Institut für Eisenbahnwesen und Verkehrssicherung IfEV TU Braunschweig

UNIVERSITY OF ŽILINA
Faculty of Operation and Economics of Transport and Communications

IDEALCAREL

Inclusive Digital Education and Laboratory training by Connecting Academic Rail Educational Laboratories

Erasmus + Strategic Partnership

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INTELLECTUAL OUTPUT: 02

Title: Literature and Teaching Material

Co-funded by the European Union

TABLE OF CONTENTS:

Organisation:

University	Institute	Abbreviation	Country	Role
TU Braunschweig	Institute of Railway Systems Engineering and Traffic Safety	TUBS	Germany	Leading partner
University of Zagreb	Faculty of Transport and Traffic Sciences	UNIZG	Croatia	
University of Žilina	Department of Railway Transport	UNIZA	Slovakia	

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ABSTRACT

The education process for professional transport subjects is a very complex system. It takes place under conditions of interaction and the conditionality objective (logical and gnoseological) and subjective (psychological) factors. From the perspective of cybernetic science, teaching can be understood as a kind of governance as a purposeful activity aimed to develop the psychical processes and system of control properties. Consequently, the factors governing the system (teachers) are rightly set out requirements for planning the teaching process. These factors are valid, including a mastery of the subject curriculum and its didactic transformation into the student's operational language. Only after it can be expected that the pedagogical activities of the teacher will be purposeful, conceptually clarified, operational, creative, and ultimately effective.

The teaching of technical subjects demands logical thinking and imagination. Using illustrative examples of the real process is one of the ways how to make the learning process simplify.

Planning and infrastructure optimization, scheduling, and sources of management practices in transport hubs and the transport network cannot be done without a thorough and objective assessment of the consequences of the decisions.

However, the transport hubs and transportation network represents a complex dynamic system. There are complex links among its elements service processes have complex interdependencies. A lot of them have stochastic status.

The purpose of this task is to develop theoretical knowledge and its application in practical skills in the systematization of professional issues and detailed knowledge of all aspects of the management of transport processes in rail transport.

The intellectual output is to work out the relevant study materials that are suitable for distance education in special conditions of railway laboratory training. The main objective is to support practical exercises in the railway laboratory through innovative approaches, in particular software support and multimedia teaching tool support in digital education.

1. INTRODUCTION

The teaching of technical subjects is a very complicated and complex process and demands logical thinking and imagination. One of the choices to make in the learning process simplify is to use illustrative examples of the real process.

The planning of pedagogical activities is in many ways different compared to the programming of other human activities. This difference is given by the factors that enter the teaching process. Relatively stable educational objectives and content of the teacher's work will be conducted in variable and always well-understood and incompletely recognizable conditions (new pupils, the variety of psychological readiness, new environment, new teacher´s experiences, his/her mental condition, etc). Hereby planning of the teachers' activities based on incomplete information and therefore it becomes the role of preparing teachers for the teaching very demanding, requiring significant pedagogical mastery.

Dynamics and variability of the conditions of the teaching process make difficult the teacher's decisions about the optimal methods, forms, and means of teaching. For the reasons outlined above the teachers planning bears activities risk that the proposed procedures do not always yield the expected results. Each teaching unit is set by teachers before the solution to unplanned situations requiring swift response and improvisation. Those factors are affecting the attitudes of teachers toward planning activities.

The purpose of this output is to develop theoretical knowledge and its application in practical skills in the systematization of professional issues and detailed knowledge of all aspects of the management of transport processes in rail transport. The existing knowledge in the field of railway transport technology and operation is developed. It is the output of extensive research work and communication among project partners as well. The aimed subject is a student of bachelor or MSc study and the subjects in the railway market. The outputs of Intellectual output 1 are used also. The main objective is to support practical exercises in the railway laboratory through innovative approaches, in particular software support and multimedia teaching tool support in digital education. This step in the research work brings relevant study materials that are suitable for distance education in special conditions of railway laboratory training.

2. STATE-OF-THE-ART TRAINING IN THE LABORATORIES

2.1 Laboratory of University of Zagreb

Laboratory for railway safety is one of two laboratories established to support teaching and research processes from the domain of railway transport within the Department for Railway Transport of the Faculty of Transport and Traffic Sciences at the University of Zagreb. While in the Laboratory for modeling and simulation, students are getting closer to the topics related to railway management and organization on the railway network through the modeling and simulation of various processes specializing in computer tools, the Laboratory for Railway Safety offers students real-time practical work on available realistic laboratory equipment.

The primary purpose of the Laboratory for Rail Traffic Safety is to demonstrate and simulate the operation of devices that ensure a high level of railway traffic safety. The Laboratory consists of two segments:

A. Signaling and safety devices and other equipment and accessories, and
B. Railway network model with rolling stock models.

The first segment encompasses railway signaling and safety devices and circuits positioned on the track and the train and the simulations of the interactions between the devices.

The mentioned equipment includes:

- laboratory test and simulation kit for the AUTOSTOP device RAS 8385,
- an axle counter with wheel sensors and a track and wheel simulator,
- test kit for train detection devices for switching on / switching off level crossings, and
- other equipment and programming controllers.

The purpose of these devices is to visually and practically demonstrate their primary functions, which are identical to the real ones, that is, the specific operation of the individual parts of each device.

A. Signaling and safety devices and equipment

A.1. Simulation and testing kit for automatic train protection device RAS 8385

The simulation and testing kit for the automatic train protection device RAS 8385 is used to demonstrate the operation of the automatic train protection system based on inductive action between the rail and locomotive part of the equipment of the INDUSI system.

The RAS 8385 auto-stop is used to protect the train automatically. The kit includes two railway balises; a combined track balise (1000/2000 Hz) and a railway track balise (500 Hz), which simulate the operation of the auto-stop device. The Auto-stop device is connected to the locomotive steering cab simulator with a speedometer, occupied cab selection (the driving direction), and other assistive devices that the driver can operate while driving.

This device contains several subsystems that locomotives are equipped with and serves as safety equipment, i.e., a device for automatic protection of train driving (ATP system).

A.2. Railway track occupation detection simulation set

The railway track occupation detection simulation set is used to simulate the axle counter device BO23 that detects the occupation and clearance of track sections at railway stations (e.g., occupation of switches and station tracks) and on the open track (e.g., automatic block sections) based on the difference in the number of input and output axles in the observed section.

The set includes one interior device BO23 - UNUR, outdoor equipment BO23 - VUR, and wheel sensor ZK24-2.

A.3. Testing kit for axle counters used to switch on and switch off warning equipment at level crossings

The kit is used to test the presence of a train using the axle counters that activate and deactivate warning equipment at level crossings.

Axle counters activating and deactivating warning equipment are part of level-crossing safety devices.

Passing a magnet above the axle counter ZK-24 simulates a train passing over the activation and deactivation points that activate and deactivate the level crossing.

A.4. Track circuit model

The railway track circuit model shows the students how detection via an electric track circle works. The model includes a track circuit relay group, two transformers, and the models of railway vehicles and track.

This model aims to demonstrate the work of an isolated section for train detection.

A.5. Magnetic wheel sensor

This type of wheel sensor uses permanent magnets without special electrification along the track. They are usually used as sensors for activating and deactivating automatic level crossings.

A magnetic wheel sensor is used for railway vehicle wheels passing over the sensor.

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A.6. Electromagnetic lock

An electromagnetic lock is used to improve the safety of railway traffic. This device uses a relay to achieve the safety logic of railway processes.

The electromagnetic lock prevents the train dispatcher from allowing trains to ride on the open track if there is a possibility that the switch is not positioned in the correct position for that ride.

A.7. Robel point lock

This switch point lock is used for locking a set of switches in the correct position for safe train operation. This lock is mounted on the outer side of the track, and it has a special detect lever that can be pushed and locked into position by a unique key. The key can be removed from the lock only when it is locked. Thus, the position of the switch point can be determined with certainty.

A switch lock is the safety element of a switch that ensures that the switch is set in the correct position that cannot be changed after locking the switch point lock.

A.8. Programmable logic controller (PLC)

Programmable logic Controller (PLC) is used to show and explain to students an introduction to logic programming processes in railway transport (e.g., the operating logic of the equipment for securing a level crossing, dead man's switch, etc.).

The Programmable logic controller (PLC) contains a random-access memory, durable memory microprocessor, control, data entry buttons, and screens to display output data or active processes. PLC is also equipped with an interface for connecting wire inputs and outputs. PLC is used to run programs stored in permanent memory and has eight digital inputs and six outputs. The maximum power consumption of output is 5.5 W.

A.9. ROBOTICS TXT Controller

This controller controls various physical models of train control systems such as level crossings, automatic block systems, etc.

The compact ROBOTICS TXT Controller (90x90x25mm) can effortlessly operate using the 2.4" colour touch display. The combined Bluetooth/WiFi wireless module provides a wireless interface for numerous applications. The many different ports include a USB host connection, where USB sticks and devices like the Fischertechnik USB camera can be connected. The integrated micro-SD card slot allows the memory capacity to be expanded. Multiple TXT controllers can be connected to a WiFi network. The controller has eight digital inputs and four outputs.

B. Railway model

The second segment encompasses a railway model of the railway network with models of railway locomotives, electric- and diesel-motor units (EMU/DMU), and passenger and freight wagons. The purpose of the model itself is to represent the real-life operation of the entire railway system in scaled conditions. Since the railway model is equipped with signals and is operated by a computer, it is suitable as a hands-on teaching tool for students to independently learn how to manage railway traffic at a different railway station. The model depicts different types of railway station layouts and two-block signalisation. The stations vary in different types of tracks and different track groups. The model is also equipped with automatic decoupling and train detection devices throughout the track network. The model can be operated from one lecturer and four student computers.

B.1. Railway Model

The railway model is used for different exercises in courses on rail transport and to promote rail type of transport among students to get them interested in studying this type of traffic.

The four-station model is built on top of a U-shaped desk to provide easy physical access to all model sections. The model is used to simulate locally controlled rail traffic.

Features:

- surface – 16 m2
- total track length – 116 m
- number of switches – 65
- number of stations – 4
- number of signals – 104
- number of railway crossings – 2
- number of towing vehicles (locomotives, DMU and EMU) – 11
- the number of towed vehicles (wagons) – 50.

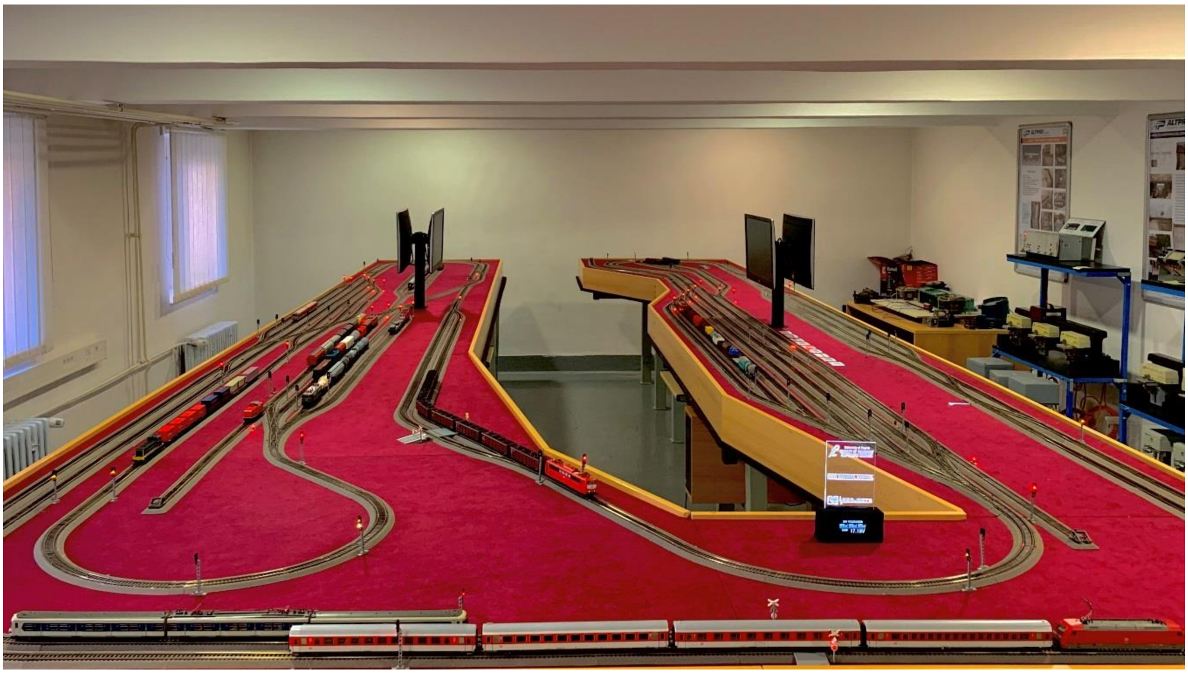

Fig. 1. Railway model

C. Stations, workplaces, and purpose

The railway model is located in the central part of the Laboratory and allows students to understand the organisation and management of railway traffic. The model is equipped with four stations connected with 116 meters of track and allows students to manage the operation of trains in their assigned station or wider controlled area. Also, it is possible to create and simulate specific technological activities within a particular railway station in addition to the train ride itself. The model consists of 4 control points for students and one point for the professor, whereby supervision over the entire model or each element of the model is possible at any of these 5 points of work. Each of the students manages the rail traffic in their station area and performs the task of regulating the traffic of trains with neighbouring stations and other actions in the station. Other operations include shunting, assembling, and disassembling trains, placing wagons on loading/unloading tracks, cleaning and maintenance places, and installing locomotives for the repair and maintenance of the depot. The stations are functionally divided, where each is specific and alphabetically named (Station A, Station B, Station C, and Station D).

Station A

Station A is the simplest station on the railway network with an intersection function. Passenger and freight trains in this station can be stopped or pass it and/or cross, pass, or overtake each other if necessary. The station is connected to Station D by a double-track line equipped with automatic block protection. On the other side towards Station B is a double-track line with interstation dependency. Station A is fitted for this purpose with four tracks (2 main passing tracks), two sidings, and two home and eight exit signals. Shunting is not allowed in the station, so it is not equipped with shunting signals.

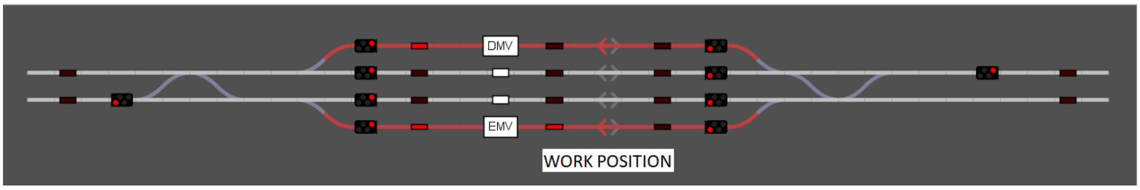

Fig. 2. Schematic view template of Station A

Station B

Station B is in the function of the scheduled station. It is located between the passenger part of Station C and Station A, which is connected by a double-track line that is interdependent with Station A. It is connected to the passenger part of Station C by a single track, where traffic runs at a distance between stations. Station B has seven tracks that serve to regulate the movement of trains. The fifth, sixth, and seventh tracks are used for receiving and dispatching trains and are equipped with boundary track signals. Other tracks are used for shunting, maintaining, and garaging wagons and trains. Station B is also equipped with two pull-out tracks to pull shunting trains and temporary accommodations for shunting locomotives. From track 7 of Station B, four tracks are separated, which are intended for the maintenance and settlement of wagons and locomotives (depot tracks). The station is designed to cross, pass, or overtake passenger and freight trains and introduce freight trains into traffic. For this purpose, it is equipped with ambiguous input, output, shunting, and boundary track signals. Also, due to its online function and the convenience of making the Further method of assembling trains, it is equipped with seven wagon decoupling. There are 28 different types of switches in the station.

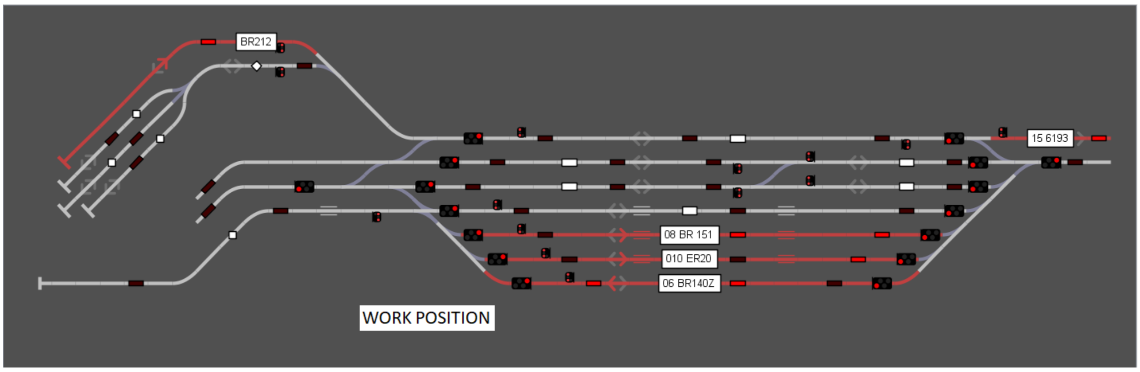

Fig. 3. Schematic view template of Station B

Station C

Station C consists of 2 technologically separate parts, the passenger part, which is intended for stopping and crossing passenger trains, and the freight part, which is intended for receiving, dispatching, assembling, and disassembling trains and placing trains at the loading point that simulates the operation of the container terminal. Station C has 2 tracks in the passenger part of the station, 4 main tracks in the freight part of the station, one short pull-out and one truncated track, and a connection to 3 tracks that simulate loading and unloading tracks at the terminal. The passenger part of Station C is connected by a single-track line with Station B and a semi-double-track line with Station D. Also, on the B side of the station, there is a track connection of the passenger with the freight part of the station. The freight part of station C is connected by a single-track line with Station D so that trains from that freight part can travel in all directions. Station C is equipped with home signals, the passenger part with group exit signals, and the freight part with main and shunting signals. There are 15 different switches in the station.

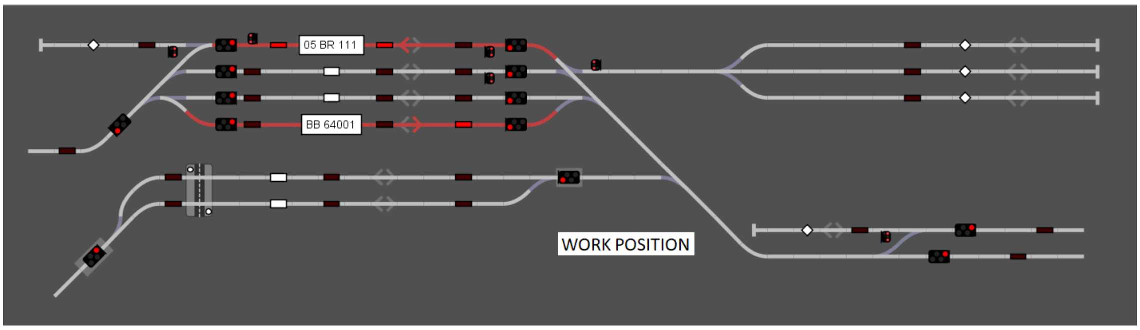

Fig. 4. Schematic view template of Station C

Station D

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According to its function, Station D is a detached and intersection station. It is connected by a double-track line equipped with automatic block protection with Station A, a semi-double-track line along the passenger section of Station C, and a single-track line with the freight section of Station C. Station D has six tracks. They are the function of stopping, starting, crossing, passing, and overtaking trains. For this purpose, the station shall be equipped with home, exit, and shunting signals. There are 19 different types of switches in the station.

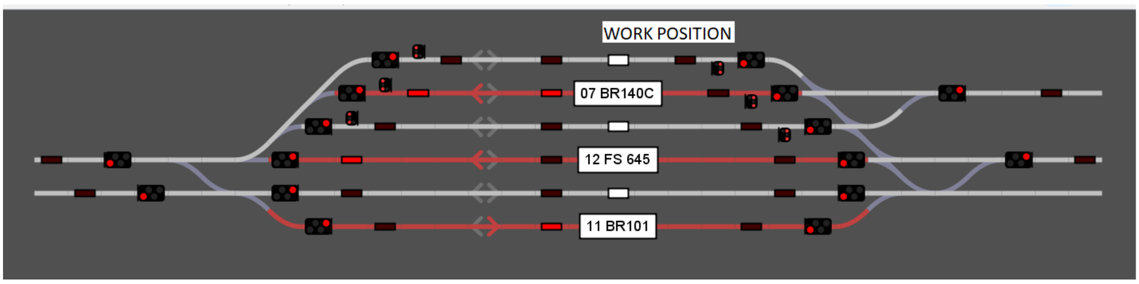

Fig. 5. Schematic view template of Station D

The entire model is equipped with two operational railway-road level crossings and vehicle detectors (feedback), which allow a towing vehicle to be detected on each part of the model. All speeds operated by trains are moderate, representing the actual speed reduced 87 times (HO 1:87). The same standard scale moderates all elements of the railway model. The model allows control and an automatic set of all intended train routes. Also, by clicking on a specific element to change it, all elements immediately change their state and position.

The model is controlled by Digital Command Control Standard (DCC). DCC is a standard and recommended practice defined by the NMRA (National Model Railroad Association) in North America and NEM (Normen Europäischer Modellbahnen) in Europe. All DCC electronic equipment is produced by LENZ Digital.

Software iTRAIN

A commercial iTrain software package controls the rail model connected to computers by the Ethernet network and the DCC digital communication interface Lenz. The program manages all connected components of the railway model, such as towing vehicles, signals, switches, road-rail crossings, and other elements. iTrain has the following features:

- Easy manual control of locomotives
- Indicator of driving time and travelled length per locomotive
- Flexible management overview interface
- Automatic control with one or more feedback per bloc

- Automatic loading of block features from a plan
- Easy signal configuration
- The ability to add text, platforms, and buildings at the interface
- Stop in the middle of platforms in stations without further feedback
- Fully automatic driving with or without routes
- Possible modification of definitions at all times (directly visible)
- Control a single layout over multiple computers on a network
- Multiple management at the same time.

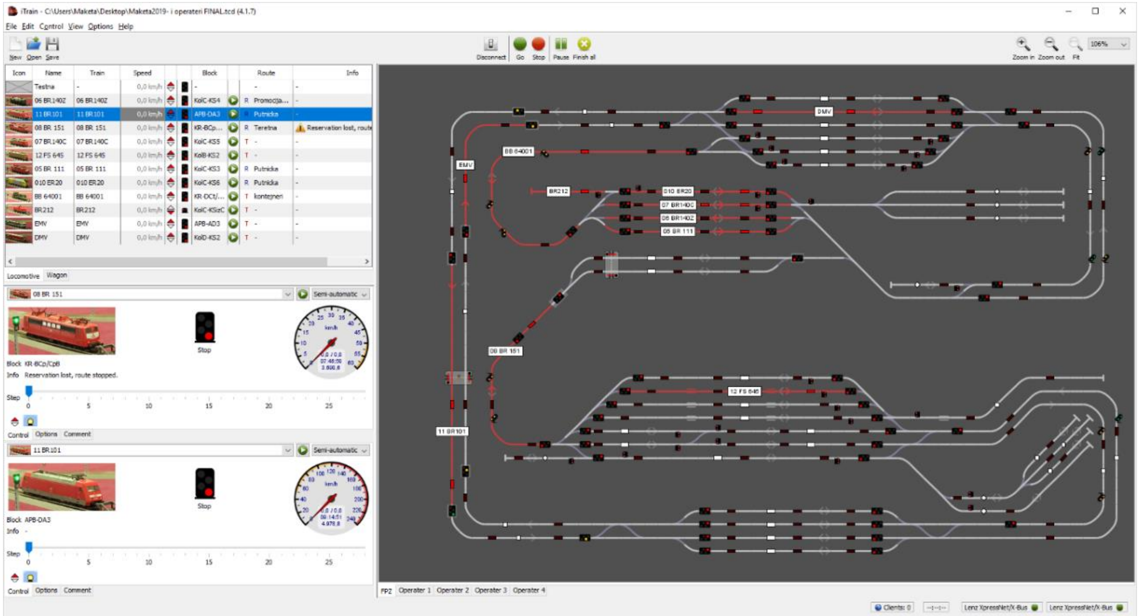

Fig. 6. iTrain test interface of all elements on the model

iTrain also controls all rolling stock (with digital address) in the model and tracks occupation. The work interface on iTrain software identifies three main areas:

1. The overviews in the upper left corner give an overview of the status of all locomotives and wagons and give immediate control over their main functions.
2. The control or throttle in the lower-left corner gives more control over all the settings of locomotives or wagons and is meant to control it in detail.
3. The switchboard on the right side is a simplified drawing of your layout, in which you see where your trains are and the state of all turnouts, signals, and other objects. You can also change the state of all objects.

iTrain allows three different types of trains operation:

- Manual,
- semi-automation,
- automation.

Manual means all elements in the route (switches, signals) are put manually one by one in the correct position for this route. When all elements are set in the correct position, choose a train or locomotive and manually drive to the aim point.

Semi-automatic control implies a control train route from a start position to a finish position. That means, choose a locomotive or train, and put in in aim point and the software will automatically put all elements included in this route in the right position, and the train or locomotive will be operating respecting all rules for this part of the line (signals, speed, direction, track occupation).

Automatic control means that the train or locomotive operates fully automatically from the start to the finish point. The route must be prepared and predefined by the operator for this train-driving operation. In this situation, all elements are set automatically, paths are forwards reserved, and if some track is occupied, the train will be dispatched. If not any solution will stop on signal and wait.

2.2 Laboratory of University of Žilina

The Transport Laboratory of the Department of Railway Transport at the Faculty of Operation and Economics of Transport and Communications (FPEDAS) of the University of Žilina (UNIZA) was designed in 1992 and has been in operation since 1994. The primary goal of creating the laboratory is to support practical training in the railway transport study program. As part of the course, students will get acquainted with the construction and operation of railway signalling equipment used in the network of Railways of the Slovak Republic (ŽSR) and will practically use the theoretical knowledge in railway traffic operation. However, the laboratory is used in teaching students of the study program Process Management and Applied Telematics of the Department of Cybernetics. As part of laboratory training, students build on theoretical knowledge of the principles of railway traffic operation and gain practical experience. This forms the base of knowledge and skills, on which they build further acquisition of knowledge in other subjects of transport and transportation, as well as economic and management disciplines. Teaching in the transport laboratory fully replaces the work of transport staff in real railway operations. A great advantage of laboratory training for students is the possibility of slow, gradual operation of railway signalling equipment, which allows them to practically check the importance of each step of operation without undue disruption of railway transport. Compared to the internship, the student has the opportunity to independently operate the security equipment in professional training long enough to be able to understand its operation and function. In the text, we present the characteristics of this transport laboratory, even though 2020 the project of a new transport laboratory has expired and is currently being implemented. Reconstruction of the premises and subsequent implementation of the new configuration of the track and signalling equipment is in progress.

The Transport Laboratory is a special classroom equipped with station and line interlocking devices, supplemented by a model track size H0 (scale 1:87). The laboratory equipment allows to simulate of railway traffic and teaches students how to operate individual types of the station and line safety devices used in operation at ŽSR.

Fig. 7. View of the model railway circuit in the UNIZA laboratory

The traffic is modelled on the 1:87 scale model railway circuit, where there are five railway stations. The transport laboratory makes it possible to practice railway traffic operation technology without the risk of causing negative effects on real traffic, dealing with emergencies, fault conditions, etc. It allows students to get acquainted with the operation and function of various types of interlocking devices - from the oldest (but still used) to the most modern. It also expands the theoretical knowledge gained in the field of security technology, as students have the opportunity to see the practical implementation and function of most systems.

The transport laboratory allows:

- be able to operate individual types of safety devices,
- to ensure full train movements in accordance with traffic regulations,
- use the train traffic diagram with the possibility of its various applications,
- operational control by the train dispatcher,
- acquire important decision-making habits in practice in various operational situations.

The transport laboratory is mainly used for teaching bachelors and engineering students. It is mainly a subject of laboratory traffic training, which is compulsory for the bachelor's degree. The laboratory is also used for scientific research activities of the Department of Railway Transport.

The track is built on a wooden table and arranged in the shape of a simple oval 48,5 x 2,5 m, on which are five consecutive railway stations of various sizes. The stations are interconnected by single-track and double-track sections. The stations are equipped with various types of station safety devices. The equipment of the transport laboratory with the use of computer technology models the operation of the following types of station security equipment:

- electromechanical station safety device of the Rank 5007 model with mechanical switches controlled by exchange levers and light signals (Vrútky railway station),
- relay station interlocking device type TEST 14 (type electric switchyard, Bytča railway station),
- relay station interlocking device with a road entry method type AŽD 71 (Hričov railway station),
- relay station interlocking device with a road entry method of the AŽD 71 type with digital dialing (Púchov railway station),
- electronic station safety device with a way of entering the road using a computer and displaying the status of the controlled process on a colour screen (Žilina railway station).

The stations are interconnected by single-track and double-track lines, which are secured by the following types of line signalling equipment:

- bidirectional semi-automatic relay block without a gate station (without compartment signals) on the track,
- automatic gate without partition lights,
- two-way three-character automatic block with full block condition.

Trains and shunting paths are organized in accordance with ŽSR regulations for the operation of station security equipment. Model railway trains are understood as trains of independent traction, they serve as a replacement for trains used in real operation, which contributes to the maximum adaptation of the teaching process in the transport laboratory to the conditions of real railway transport operation. The operation of the relay logic is replaced by personal computers compatible with the IBM PC AT standard compared to the actual operation. With the help of this technology, it is possible to simulate not only the normal operating states of station and track signalling equipment but also various fault states.

Fig. 8. View of the students during teaching in the UNIZA laboratory

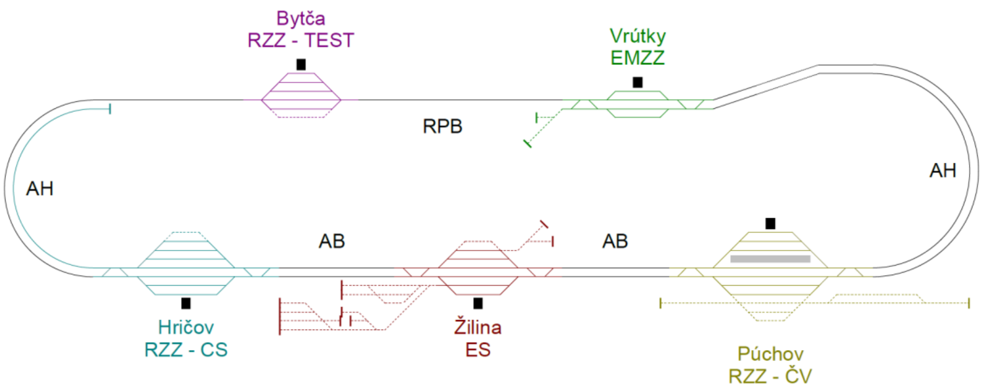

Fig. 9. Track circuit of the model railway of the UNIZA laboratory

Explanations:

- Station safety device:
  - EMZZ - electromechanical security device
  - RZZ - relay
  - ES - electronic
  - CS - Path system
  - ČV - digital dialling
  - TEST - type electric relay system
- Line safety device:
  - RBB - semi-automatic relay block
  - AB - automatic line block
  - AH - automatic block signal

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The train dispatcher may, through:

- dispatching telephone equipment:
- announce train traffic,
  - to find out their time position during the operation of trains according to the train schedule,
  - answer dispatchers' questions and resolve disputed traffic situations at stations and on the track,
- computers:
  - take over each model railway station from local service to remote service,
  - create a simulation of fault conditions on the security device in each station.

The traffic laboratory control system is designed as a distributed system - each station has its control computer that controls the components of the model track (adjustment and control of the position of interchanges, control of traffic lights, control of model vehicles, and detection of the presence of rolling stock in individual sections) and at the same time models the behavior of the relevant type of station resp. line signaling equipment at the relevant station or inter-station section - senses the operation of control elements at the service station of the relevant equipment, based on the condition of elements in the track, and the operator simulates the operation of the device type and according to the simulation results controls indication elements at the service station and simultaneously controls model track components. The control system of individual stations is conceptually solved in the same technical and programmatic way. From a hardware point of view, each station uses a centralized control computer and decentralized input and power output circuits located close to the controlled and monitored elements. A schematic diagram of a control system for one model station is shown in figure 10.

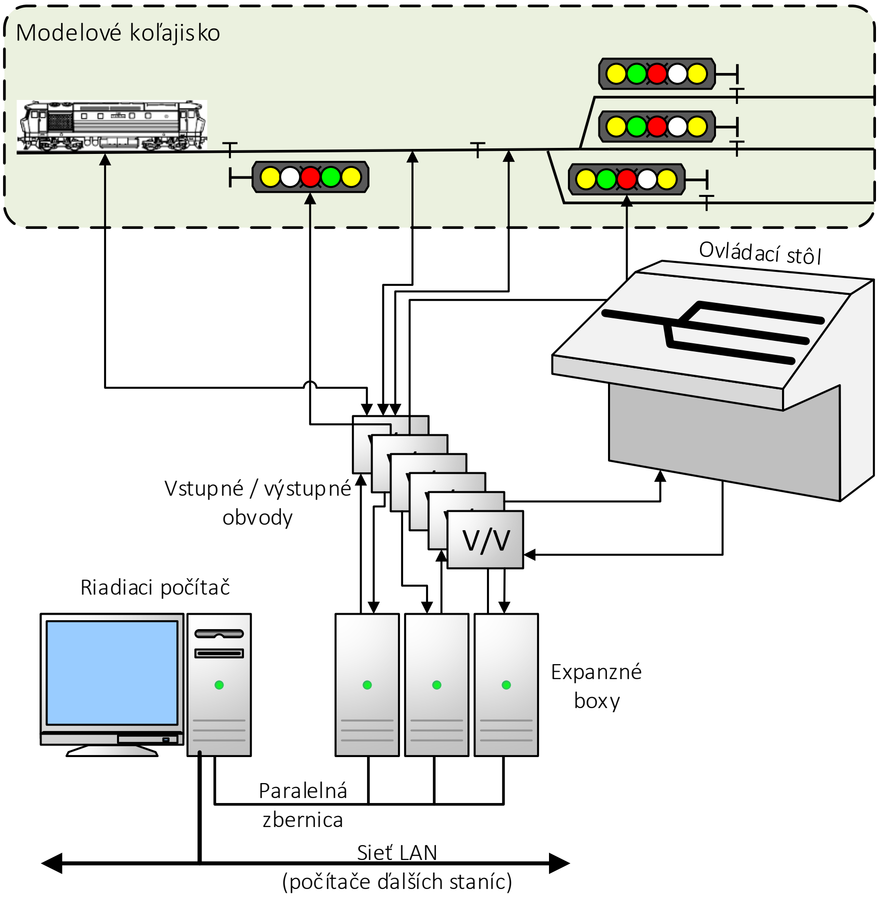

Fig. 10. Principle scheme of steering of the model station

Fig. 11. View to the model railway station

The transport laboratory currently has a telephone system consisting of an automatic Panasonic EASA PHONE 308 PBX with connected Panasonic KX-T7030XHK system telephones with push-button tone dialing and an LCD unit. All dispatchers' workplaces are equipped with telephone sets. The workplace at the Vrútky station is additionally equipped with a manual switch with telephones powered by a local battery. This device is used to connect the dispatcher's workplace with the workplaces of signalmen on the dependent signal boxes St.1 and St.2.

The proposal for the **renewal of the transport laboratory** includes modernization for the need of providing innovative education. It is necessary to build the room and build a model railway as a simulation model in connection with control and security systems. The elements and configurations of stations with relay interlocking devices and with an electromechanical interlocking device will be preserved from the existing equipment of the transport laboratory. A new, internal line circuit for remote traffic control will be built. During the modernization of the transport laboratory, additional model railway stations and inter-station sections will be added. The extension is limited by the layout of the room and the size of the table that will be retained. When upgrading, we recommend the topology of the model track according to the sketch shown in figure 12. In the laboratory, the basic concept of arranging the track in the shape of a deformed oval will be maintained, while the track will consist of 3 lines.

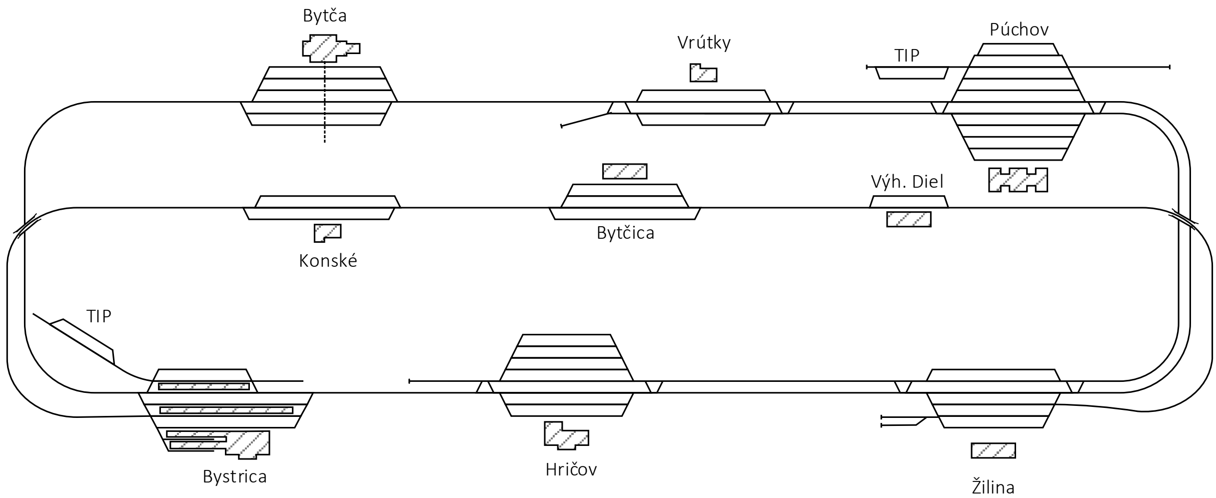

Fig. 12. Proposed model lines scheme

A concept will be maintained in which individual railway stations will be controlled by different types of station signaling devices. The topology of stations with electromechanical and relay interlocking devices will be preserved so that the panel configuration of these devices does not have to change. To complement modern equipment will be:

- One station is secured by an electronic interlocking system of the SIMIS W type with an ILTIS service station from SIEMENS Mobility, s.r.o.

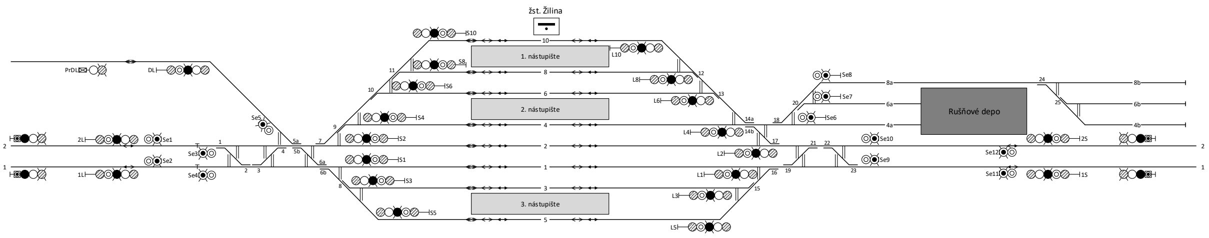

Fig. 13. Scheme of station equipped with the electronic interlocking system SIMIS

- Second, the new, station will be secured by an electronic box of type ESA 44 developed by AŽD Praha.

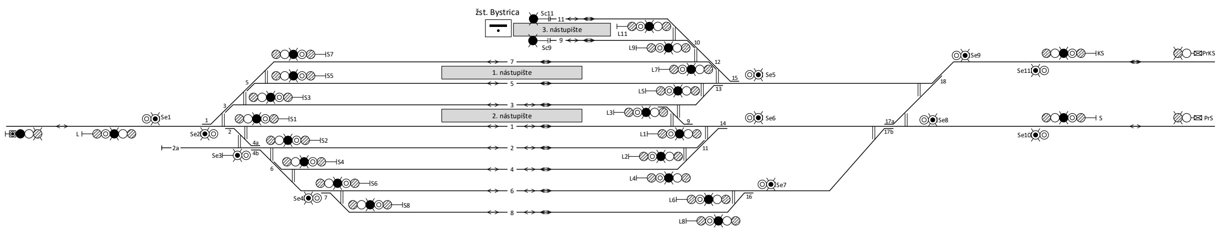

Fig. 14. Scheme of station equipped with the electronic interlocking system ESA 44

A new single-track line will be created between these two stations, which will be centrally controlled by a system of remote control and monitoring of security devices. There will be one station, one vault, and one stop on this line.

The following will be used as track protection equipment in the laboratory track:

- two-way automatic track-side interlocking device type AH 71 with compartment signals
- two-way automatic track-side interlocking type AB 3-82.
- ABE-1 two-way automatic track-side interlocking.
- two-way automatic track-side interlocking device type AH 71 without compartment signals in the inter-station section.
- two-way semi-automatic track-side interlocking device type RPB 71 without compartment signals in the inter-station section.

Analog control of all components, digital control of driving model vehicles, as well as hybrid control, will be applied in the design of the hardware architecture of the control system. Subsequently, it will be possible to supplement the ICT superstructure for remote control. In the future, it is planned to supplement the traffic control centre with a simulator of remote-controlled lines.

In the case of the study program rail transport with an overlap on related study programs in the field of transport but also other fields focused on security systems in rail transport, this is a key objective to achieve the required spatial and infrastructural provision of educational, creative and related activities corresponding to educational outcomes with the provision of practical training traffic management in a specialized classroom. This plan will be reflected in the forthcoming Long-Term Plan of the University of Žilina in Žilina for the years 2021 - 2027.

2.3 Laboratory of TU Braunschweig

In 2012 the virtual railway laboratory (V-EBL) was established at IfEV, to give practical advice to the students. In contrast to other universities, there was no space for a big model railway controlled by real signal box interiors. Instead, train moves are simulated by a computer in a virtual network controlled by user interfaces of the same type as used on real railways. Since train moves cannot be watched on a physical model, all kinds of control systems can be used that are equipped with continuous line clear detection and an automatic block system. They can be operated by either relay panels (simulated on computer screens) or electronic control consoles as used in operation control centres.

The laboratory network consists of five train controller workstations, among them four student workstations and one supervisory workstation. The workstations are located in separate cubicles but connected by IP interfaces (Figure 1). To reduce the effort for local training, the control districts of the operators are much smaller than in a real control centre. The control districts of the four student operators form a common network with trains running from district to district. Interfaces provide the transmission of train descriptions and block control information. At the interfaces to the 'outer world', arriving trains are created by the simulation, and trains leaving the network are deleted. The simulation also provides train descriptions and block control information at these interfaces. The screens of the supervisory workstation show an overview track chart of the entire network. This workstation is mainly used as the trainer workplace in student training sessions but may also be used as a dispatcher workstation in sessions that require a separate person for traffic regulation.

In a separate room, there is a locomotive cab simulator based on the real cab of a former DB locomotive (Figure 16). The cab simulator is not yet connected to the network simulation but has its infrastructure model.

Fig. 15. Workplaces for interlocking and train control

Fig. 16. Train cab simulator

Interlocking and train control

The laboratory has three different virtual networks:

- A fictitious German network controlled by traditional German relay panels (software: Signalsoft)
- A British network based on a real infrastructure and controlled by Network Rail's IECC user interfaces (software: SimSig)
- The underground part of the Cologne Light Rail network controlled by the user interfaces as used in the control centre of the Cologne transit authority (software: Bahnsim)

Signalsoft

The software used for the German network is based on a customised version of the signalling simulation software of the Canadian software company Signalsoft Rail Consultancy Ltd. from Lucan, ON (www.signalsimulation.com).

For international teaching, Signalsoft developed a generic user interface that can be adapted to the operational and signalling principles of any railway worldwide. In the laboratory, it is used with an internal control logic based on German signalling principles. While the design of the screen display differs from the design used in DB control centres, it provides a very clear visualisation of the operational situation (Figure 17). It has turned out to be a very useful tool for university education where the objective is rather to demonstrate principles but not to go into the details of the operational rules of a particular railway.

Co-funded by the European Union

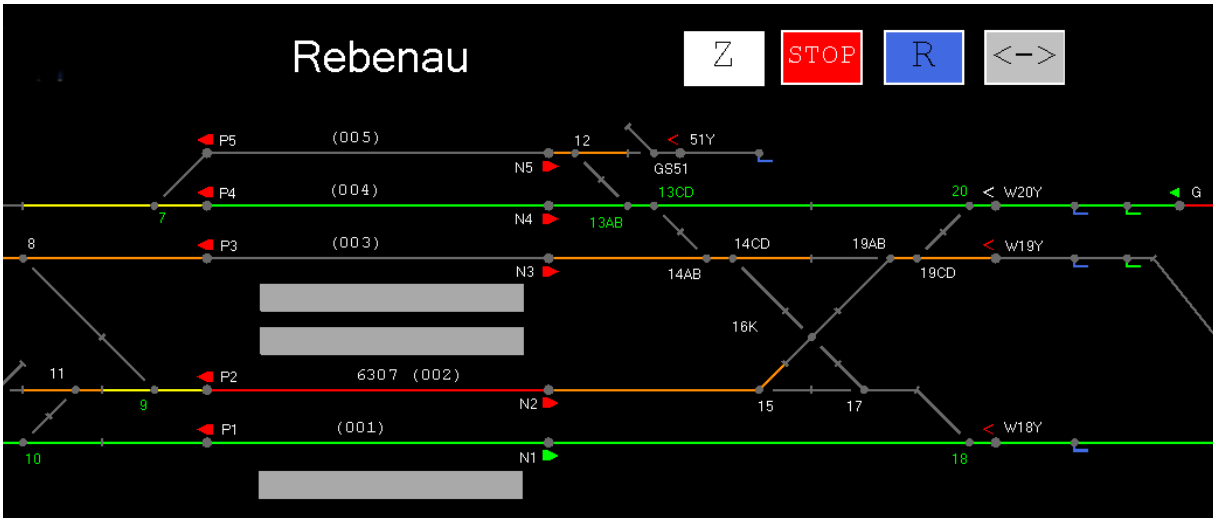

Fig. 17. Cutout from the control screen of Rebenau station

To demonstrate a legacy system, the workstation can also be switched to a simulation of push-button panels of the German relay interlocking type SpDrS60. The panels are displayed on a computer screen and operated by clicking on the push buttons (Figure 18).

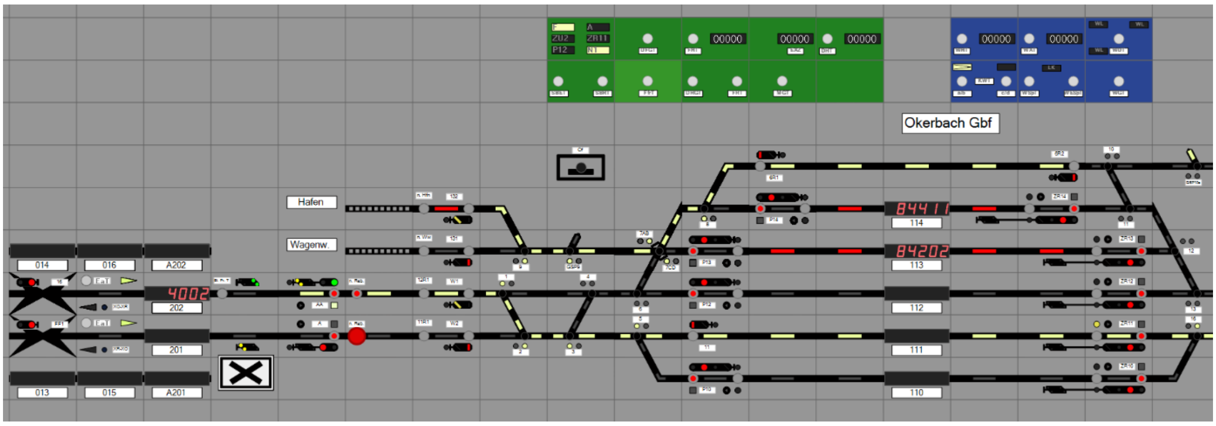

Fig. 18. Cutout from the control screen of a SpDrS60 control panel

A network of four generic stations is designed for IfEV needs with a future option of 6 stations (Figures 5 and 6).

Co-funded by the European Union

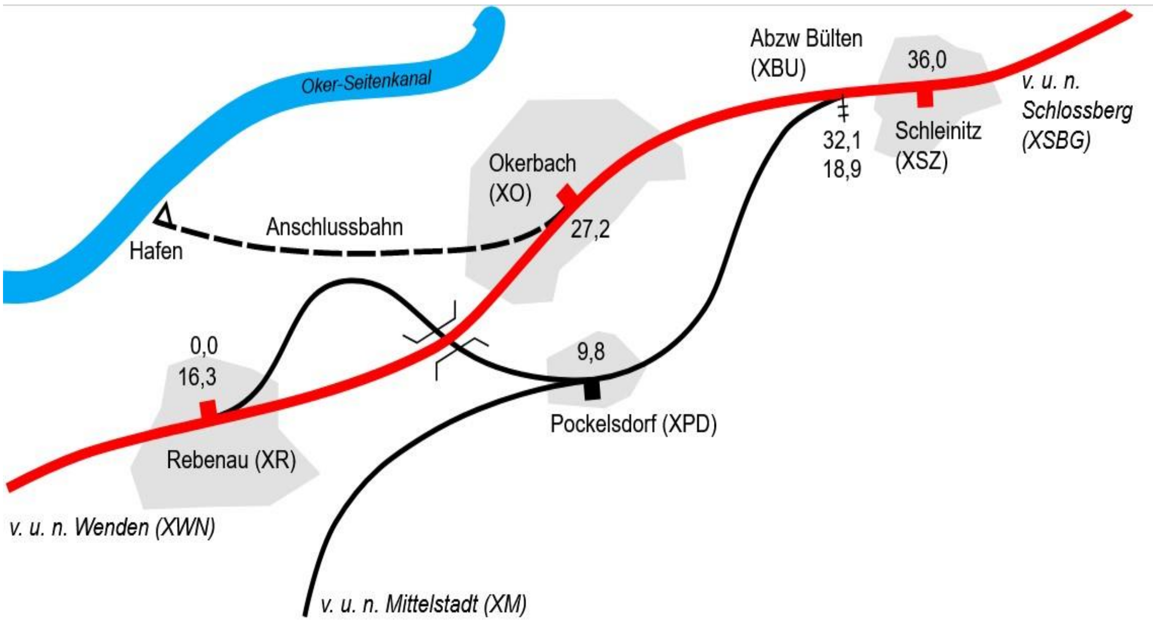

Fig. 19. Generic railway network

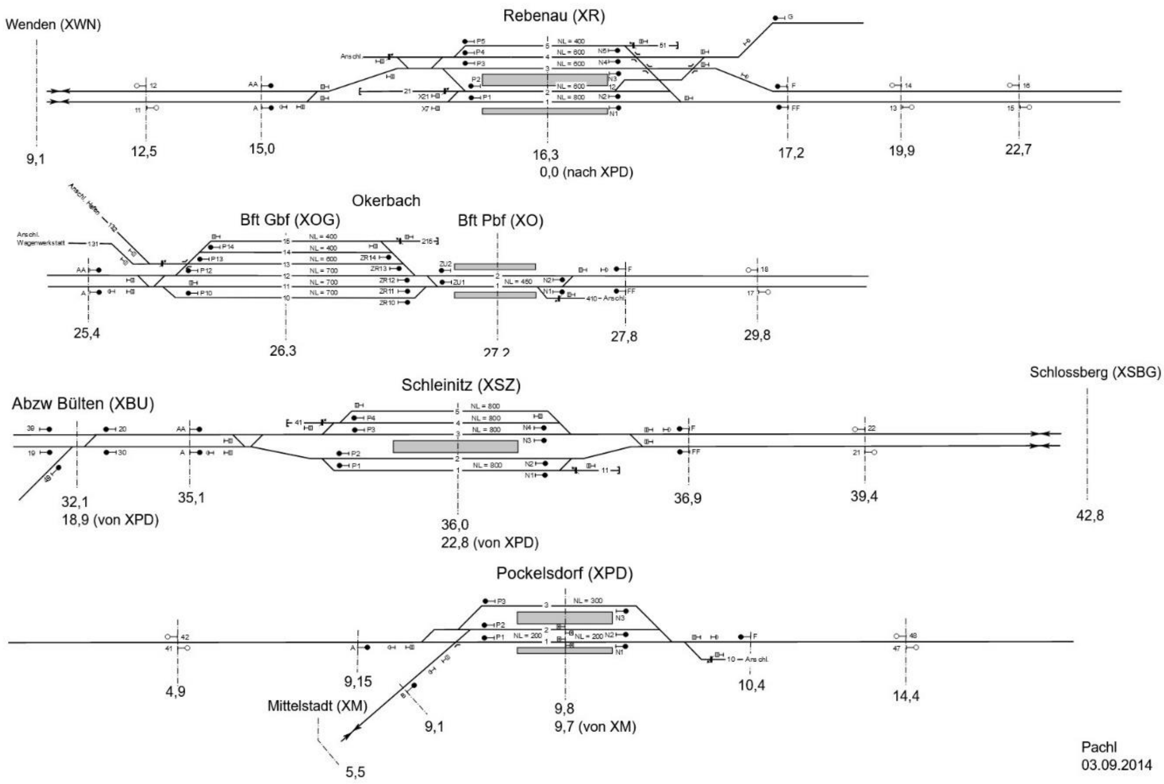

Fig. 20. Station diagrams

Three Versions of this software are in use for education. First is the standard network inside the lab with four stations and variable timetables. Second is a downloadable Demo-Version with one station and a fixed timetable for single use. That version is used by the students as an offline simulation to prepare for laboratory sessions at home. And the third option is a so-called embedded version with four stations and a fixed timetable for distributed network usage. That version is used for online sessions to replace laboratory work during the pandemic.

To make it interoperable with other simulations, Signalsoft provides an interface called "Bridge".

SimSig

SimSig is a British Interlocking and train control simulation replicating the operation of British IECCs (Integrated Electronic Control Centres). The whole British network is available.

It was designed by the British company SimSig for use in training and gaming. It has been courtesy of Hitachi, the designer of the real control centre software.

IfEV has a license for two real British regions: Exeter and Westbury (Figure 21). We use a network Version with one trainer and three (five) workplaces in the lab.

There is also a free demo version for single use available, based on the Wembley Suburban line. This version is given to all students to prepare for the lab sessions at home.

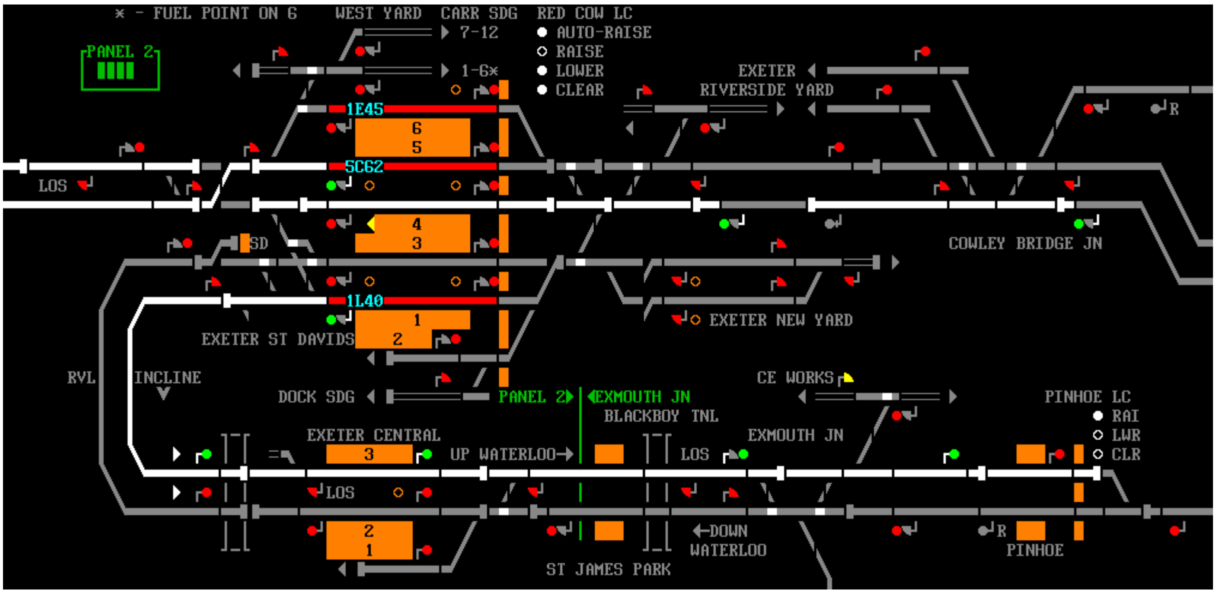

Fig. 21. Cutout of the Exeter control screen

Bahnsim /VICOS (Siemens)

For the light rail laboratory sessions, Siemens provided the IfEV with a simulation of the underground lines of the Cologne light rail system, which is operated by the Cologne Transit Authority (Kölner Verkehrsberiebe - KVB). While the KVB overground lines run in tram mode, the underground lines are signal controlled. Some control areas are controlled by electronic SICAS interlockings, while other areas still have relay interlockings of the DrS-U type. In the KVB control centre, both kinds of interlockings are controlled from a VICOS control system (Vehicle Infrastructure Control Operating System). The simulation was implemented in the software Bahnsim, which is a Siemens product. Bahnsim provides a microscopic simulation of the train moves and the interlocking functions under real-time constraints (Figure 22). This allows the control of the simulation by the real VICOS interfaces. So, the students experience a very high degree of realism, since their control interfaces look exactly like the control screens in the KVB control centre (Figure 23).

Co-funded by the European Union

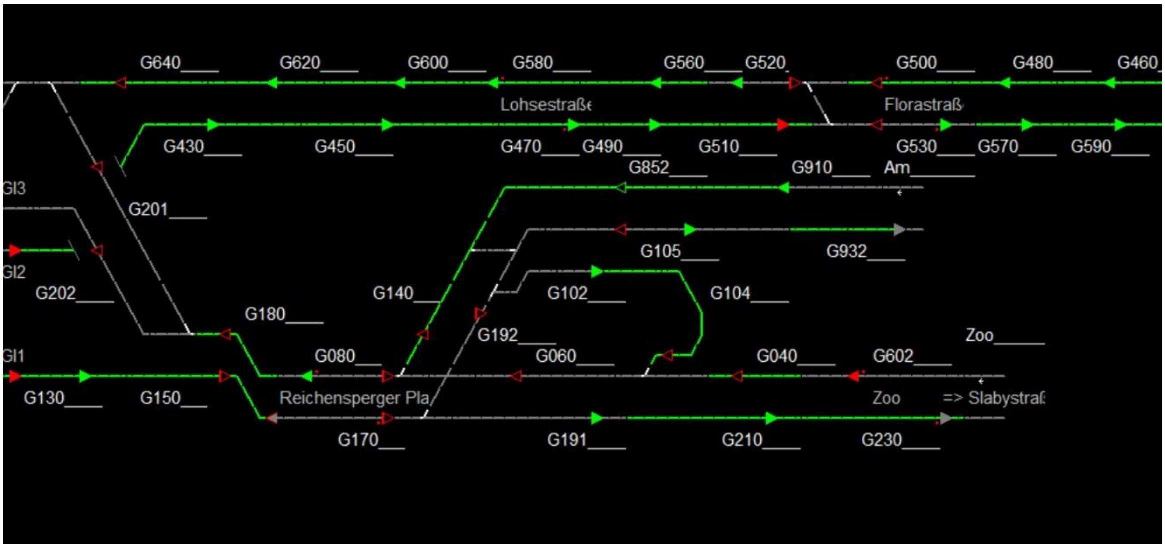

Fig. 22. Cutout from a BahnSim simulation control screen (used on the trainer workstation)

The network could be operated by four to six students plus one trainer station. It is only accessible inside the lab.

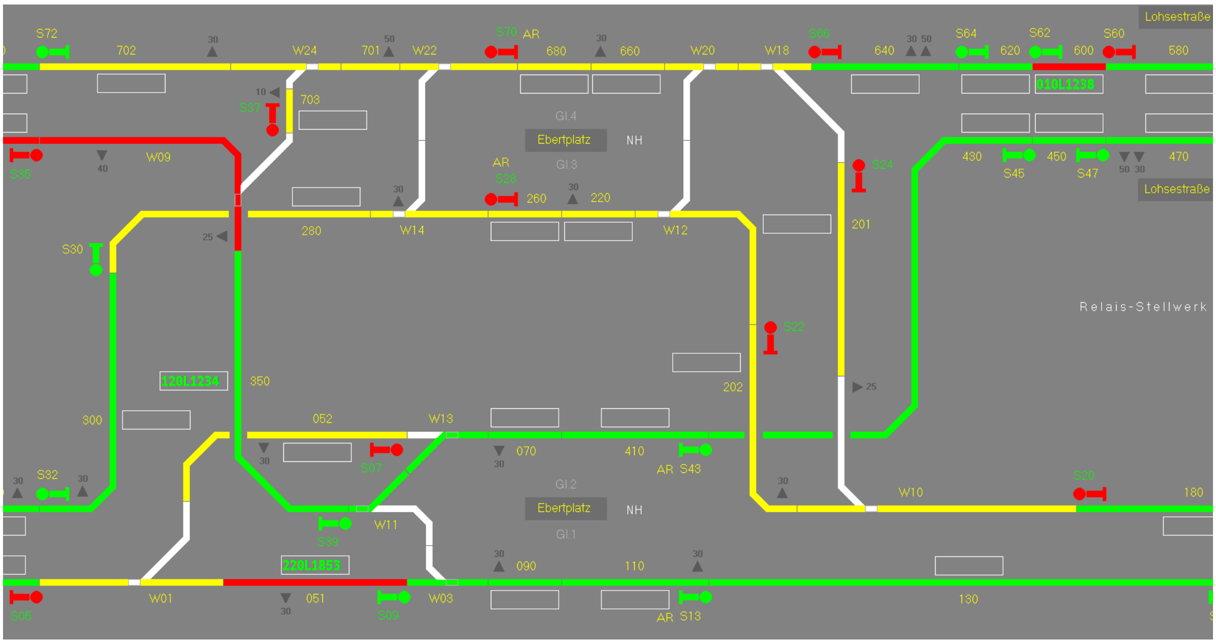

Fig. 23. Cutout from a VICOS control screen

__Train cab simulation__

ZUSI

Zusi is a cab simulation software for professional training usage, which is certified by the german federal railway authority EBA (Eisenbahnbundesamt) and is used by many train operating companies (railway undertakings), universities, and railway training schools.

It has a network of fictitious stations and lines, all German and Austrian signalling systems and all ATP systems including ETCS. The trains and timetables have to be generated by the customer with an included editor. Also available is a trainer station version with editable signals and switches, simulated radio communication, and the possibility of generating incidents.

At IfEV a real cab interior of a former control car from Rhein-Ruhr S-Bahn is used as a user interface.

Beneath the professional Version, there is available an inexpensive hobby Version with a broad user community developing lines and rolling stock.

Fig. 24. Riding along the mainline on the cab simulator

Model railway

Because of space restrictions in the lab, only one station was built for example. The small station "Pockelsdorf" also exists in the Signalsoft Simulation.

It is built in HO scale, but the length scale is reduced to 1:250. So the typical German block length of 750m is reduced to 3m in the model.

Digital train control, signalling, and infrastructure is based on international DCC (Digital command control) standard and the simulation ESTWGJ (with a standard German pushbutton interface) is used as control software. One future option is to control it by SignalSoft, but this has no DCC-interface today.

Software tools

FBS ("Fahrplanbearbeitungssystem") is a graphic timetable construction software. The software is in use in the IfEV laboratory e.g. for teaching and research projects. Students can use the software for their projects and academic theses. The whole laboratory network is modelled in FBS.

FBS is a product of the iRFP ("Institut für Regional- und Fernverkehrsplanung") company from Dresden. The FBS software is used in various railway companies, this includes Railway Undertakings, Infrastructure Managers, Integrated railway companies, and consulting companies. Also, research institutions are working with FBS. The first institution where FBS was used was the Technical University of Braunschweig in 1998.

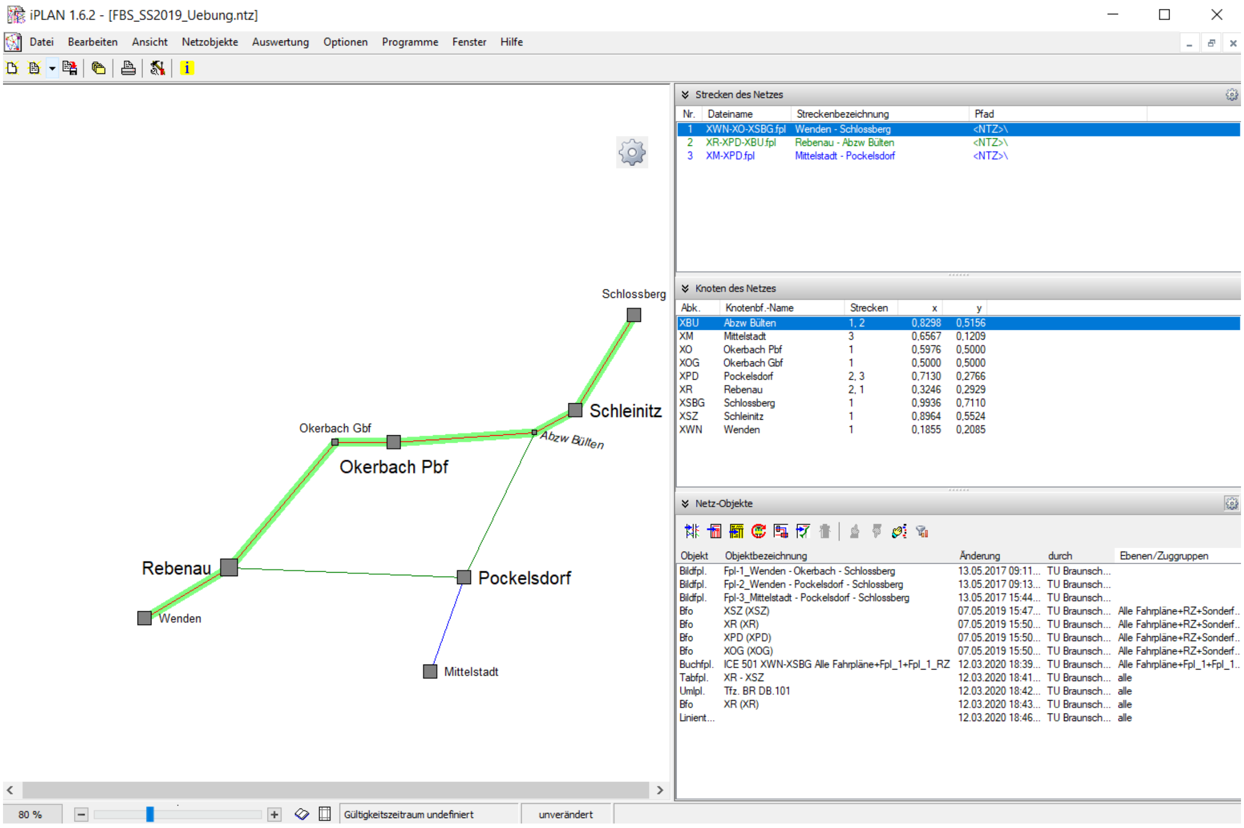

Fig. 25. IfEV Network in FBS

With an interface that was developed at IfEV, it is possible to transfer the timetables from FBS into Signalsoft. For that transfer, the RailML interface is used to export the timetables. The transferred Signalsoft timetables are stored in an access database.

FBS works with an input-output principle. The inputs are the vehicles and traffic input data (e.g. dwell time or stops). The vehicle databases (engine and waggon database) are delivered with the software.

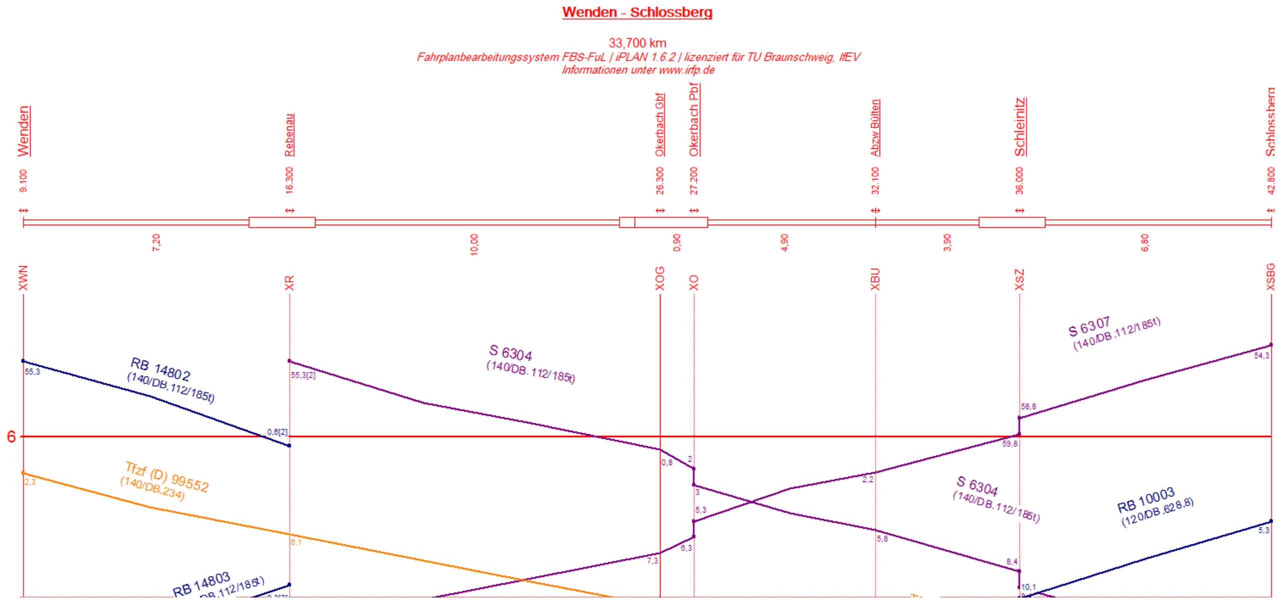

Fig. 26. *Graphic timetable*

The main workspace is the graphic timetable, where the trains are constructed. It is also possible to print the graphic timetable and use it as an operational document.

Other outputs that are used for the exercises are:

- Arrival and Departure timetables
- Circulation plans
- Customer timetables
- Drivers timetables
- Interval graphics
- Station timetables

Further Outputs that are not used in the exercises:

- Statistics
- Train data sheets
- Timetable book

OpenTrack

OpenTrack is a synchronous simulation software, that was developed as a research project at ETH Zürich. OpenTrack is now a spin-off company from Zürich. IfEV currently has 5 OpenTrack licences. The latest update was in 2020 to version 1.10.2. Currently, there is no IfEV-network is modelled in

OpenTrack. However, there are currently plans to model the Generic and British networks in OpenTrack.

Other Software tools:

Other available software tools are SLS and the ProVI construction software.

3. DIDACTICAL CONCEPT

The purpose of the research is to collect knowledge. This knowledge needs to be searched for and discovered. In the fields of engineering, compared to natural sciences and philosophy, these are found mainly within the specific results of the research. These lead to specific solutions, technological processes, or final products; in contrast with philosophy or the natural sciences, where the research or study is ideally a matter of impartial objective of mind.

Scientific research is the development of means of transport didactics of vocational subjects. Its characteristic features are:

- Objectivity
- Verifiability
- Methodically
- Reproducibility

Conformably to their aims of transport research can be subdivided to:

- Basic (this typically takes transport as theoretical science)
- Applied (uses exact methods and their potential applications of transport)

A solution to difficult problems requires originality - a new approach of mind, a willingness to explore new horizons, maintaining objectivity, and endurance even through failures.

3.1 The problem interpretation

The essence of creative interpretation is the activity, independence, and creativity of students. It is the most effective method of learning specialized subjects of transport. The student is an active participant wondering just to acquire the scientific or technical problem (origin, evolution, default hypothesis, critical points, doubts, and weaknesses) with continuous verification of the accuracy of thought. The student identifies the problem.

The problem interpretation gives rise to the original visions, development of critical thinking, and creative and adaptive activity of thought. It is a school of thought in front of teacher and student dialogue about the problem.

The scenario of problematic interpretation is based on a listener dragged into the action and his/her active part in a "dramatization" teaching unit. The method requires excellent professional and teaching skills of teachers and students to be available.

3.2 The Autonomous research

The method of individual student research activities ensures active participation in instructional activities. The basis of the method is to solve the defined problem or task, at which the application or reproduction of actual knowledge is not enough to resolve them. The independent research in the teaching of transport subjects also includes the adaptation of knowledge in other conditions (nonspecific transfer).

In this method, the teacher plays the role of a professional consultant. His/her main task is to prepare some specifications of tasks and problems to be solved. The tasks are compiled to use creative knowledge and skills, the openness of variation solutions, and the participation of students in solving so-called difficult tasks. While solving the teacher is in the role of corrector, in the case the corrector of incorrect solutions on key issues (checkpoints).

3.3 The experimental research

Trainee researchers often have distorted and simplified views of the research work. He has no experience with severe problems. Systematic research work is the most important aspect. The initial phase comprises the orientation on the subject (information gathering). The next phase is represented by the preliminary results - a set of experimental conclusions. Later, it will be extended, strengthened, or rejected. A phase of substantial results is characterized by increasing knowledge improved with concrete results and conclusions. The last phase - "packaging" - means an arrangement of accumulated empirical and experimental data. It also means the theoretical justification of the results and the practical processing work (text, graphs, tables, and figures).

Methods of individual student research activities guarantee the active participation of the student in taught activity. The essence of the method is to solve a defined problem or task. Application or reproduction is not enough to solve the current knowledge. As separate research shall be deemed also the adaptation of knowledge in other conditions (unspecified transfer).

The teacher has a major role in preparing the assignment of tasks and problems to solve. Tasks are drawn up to the creative use of knowledge and skills, openness of variation solutions, and involving pupils in solving so-called difficult tasks. The teacher is a corrector of solutions, especially in case of wrong solutions to key issues (control points).

The process of scientific discovery is based on systematically arranged progress. The researcher, working individually or in the research group, establishes the vision of the outcome of their own already acquired knowledge. The result arises through a certain methodology.

For applying research teaching methods, a teacher must base on precisely defined grounds, that students already must have previously acquired (Prerequisites).

3.4 The tasks which lead to the needed output.

Task 1 is aimed at the teaching module's elaboration. The development of methodological study materials for the use of simulation tools in the teaching of laboratory traffic training will be crucial. Modern teaching handbooks will support new methodological teaching approaches by using the internet, sharing, and digital platforms. Creating materials to support laboratory training means creating intellectual property, summarizing existing procedures, individual specifics of traffic management rules, as well as national differences. Continuous communication between project partners leads to the creation of structured knowledge in the form of teaching materials and a unified form for students and users. Each partner analyses the teaching materials for the conditions of its laboratory training and structured materials are created with a uniform arrangement containing common provisions for achieving interoperability, as well as national specifics. The handbook for teaching staff with information for an implementation of laboratory training education for transport engineers with literature links, potential topics, best practices, etc. is the aim of this intellectual output The teaching materials should be adapted for fully supporting distance learning. This output is coordinated with Intellectual output 3.

Task 2 is aimed at a didactical and methodological approach. The task identifies the appropriate methodological and didactical approach in the new circumstances of digital education. On the ground of the current state of education in all laboratories, the possible approach for collaboration among partners is developed. Proposal of a methodology for the innovation of technologies for the control and modeling of transport processes with the support of software tools.

Task 3 contains the analysis of the current state of the teaching materials for students.

Task 4 brings the laboratory training content that is developed in dependence on the type of laboratory.

4. DIDACTICAL AND METHODOLOGICAL APPROACH

The main target groups are rail transport major students of undergraduate and graduate transport study programs. The number of students will remain the same during and after the completion of this project since the capacity of each laboratory will remain the same because there is no planned expansion of laboratory infrastructure. The exact number of students during lectures is limited by each laboratory capacity with the average maximum number of students per lecture being 15-20. For best results and student active participation, it is best to limit the number of students to a maximum of 10 per lecture/practical exercise.

Learning objectives that the students will achieve are in direct connection with the use of the Railway network model and simulation of railway operations, which will be their main learning environment. After course completion, students will be able to define all quintessential elements of railway infrastructure and rolling stocks as well as fundamental principles of railway simulator. Furthermore, students will be able to calculate station intervals and apply them to the railway model. By using a specific software package for controlling train movements on the railway model, students will be able to organize complete train journeys between selected stations for both passenger and cargo trains as well as shunting operations, as needed. In case of extraordinary circumstances (train derailments, level crossing accidents, unscheduled track maintenance…), students will be able to find alternate routes and organize railway traffic according to these circumstances.

Each student's performance is evaluated based on a specific assignment that he or she receives from the teacher, meaning that students have a specific time frame to organize train movements (passenger, cargo, or both) between selected stations and make sure that all national regulatory safety requirements are being met. Furthermore, teachers will introduce a certain extraordinary event mentioned before, to assess students' ability to adapt to these new events and to organize railway traffic accordingly.

By using practical exercises within laboratory settings, students will be able to better comprehend theoretical knowledge acquired in a regular classroom, and also they will be able to visually observe real-time changes in the organization of railway traffic on the physical network model in scaled conditions, based on real-time modifications using proprietary software for traffic control.

This didactic approach will be the same for every laboratory within this project because it demands the same theoretical preknowledge of railway systems to successfully organize railway traffic on the scaled railway model. The only difference would be national safety regulations and signaling systems which can slightly differ between Germany, Slovakia, and Croatia.

5. TEACHING MATERIALS FOR STUDENTS

Task 3 contains an analysis of the teaching materials for the students. The development of methodological study materials for the use of simulation tools in the teaching of laboratory traffic training will be crucial. Subsequent elaboration of teaching texts with the given issue, including multimedia support. Common teaching materials elaboration for digital education. Creation of teaching materials for each laboratory as well as national specifications. Modern teaching handbooks will support new methodological teaching approaches by using the internet, sharing, and digital platforms. The complete description and manuals for laboratory training will be elaborated as internet presentation, interactive and digital chapters, and video streaming. This will be developed as:

- Analysis of the current state of the teaching materials according to the laboratories in partners universities

5.1 Laboratory of University of Zagreb

Table 1. Overview of subjects realized in the laboratory - UNIZG

Module (Study Programme)	Lan-guage	Educational objective	Contents	Teaching material	Railway laboratory	Replacement solutions for the pandemic
Railway Traffic Technology (Railway Transport / bachelor level)	Croatian English	• define the basic terms and describe technological processes in railway stations • calculated the need for track capacities, shunters and personnel • plan railway station technology process for given timetable • connect the work of railway stations with timetable • analyze coordination between stations available capacities and work in number of trains (wagons) • estimate robustness of technological work	• Define the basic terms related to technological processes in railway stations • Understand the principles of all types of technological processes in railway stations • Make conclusions based on analysis of train and shunting operations in railway stations • Explain an impact of station technological processes on railway timetable planning	• Lecture presentation • Selected chapters from textbook Badanjak, D., Bogović, B., Jenić, V.: Organizacija željezničkog prometa, Fakultet prometnih znanosti Sveučilišta u Zagrebu, Zagreb, 2006. • Textbook exercises: Abramović, B., Brnjac, N., Petrović, M.: Inženjersko-tehnološki proračuni u željezničkom prometu, Fakultet prometnih	• railway operations in stations • shunting • shunting with stub tracks • train sorting process • timing of technological process	• Moderated online session • Moderated online session with multimedia text book support

		process for railway station • evaluate proposed solutions based on qualitative and quantitate indicators		znanosti Sveučilišta u Zagrebu, Zagreb, 2009.		
Railway Signalling (Railway Transport / Bachelor level)	Croatian English	• introduce students to the area of Railway Signalling and its implementation in the railway traffic management process	• know the role of all types of railway signals and train control devices • know the basic principles of train separation • know the basic principles of interlocking and routing trains through railway station • be able to analyze and explain the impact of train control systems on the railway traffic efficiency	• Lecture presentation • Selected chapters from textbook 'E. Anders at all: Railway Signalling & Interlocking, Eurailpress, Hamburg, 2009.' • Textbook 'J. Pachl: Railway Operation and Control 3nd edition, VTD Rail Publishing, Mountlake Terrace(USA), 2009.' • Textbook 'P. Stanley: ETCS for Engineers, Eurailpress, Hamburg, 2011.'	• Railway signs and signals and their meanings • Railway turnouts and derailers • Track clear detection systems • Station interlocking principles • Automatic train protection systems • Railway telecommunications • Basic principles of the European train control system (ETCS)	• Moderated online session • Moderated online sessions with multimedia textbook support

Railway Timetabling and Operations (Railway Transport / bachelor level)	Croatian English	• explain the basic principles of railway traffic control • basic principles of railway planning and timetabling • assess a railway line capacity • check the feasibility and stability of railway timetables and to evaluate how disturbances affect railway operations	• Define and explain the basic principles of railway traffic control • Understand the basic principles of railway planning and timetabling • Be able to assess a railway line capacity • Know how to check the feasibility and stability of railway timetables and to evaluate how disturbances affect railway operations	• J. Pachl: Railway Operation and Control 3nd edition, VTD Rail Publishing, Mountlake Terrace (USA), 2009. • 1. I.A. Hansen, J. Pahl: Railway Timetable & Traffic – Analysis – Modelling - Simulation, EURAIL PRESS 2008. • 2. UIC Code 406, Capacity, International Union of Railways (UIC), 2004.	• Basic principles of train and traffic control • Principles of train separation using timetable • Calculating blocking times • Headways and buffer times • Station intervals • Energy-efficient railway operation and timetabling • Timetable rescheduling process • Railway infrastructure capacity analysis	• Moderated online session • Moderated online sessions with multimedia textbook support

5.2 Laboratory of University of Žilina

Table 2. is an overview of the study programs and teaching subjects in the transport laboratory of UNIZA. The content, teaching material, teaching modules in the laboratory, and the replacement solution during the pandemic period also.

Table 2. Overview of subjects realized in the laboratory - UNIZA

Module (Study Programme)	Language	Educational objective	Contents	Teaching material	Railway laboratory	Replacement solutions for the pandemic

Railway Transport Operation 1 (Railway Transport / bachelor level)	Slovak	• The students can explain the fundamental elements and principles of railway signaling systems • The students are competent for operating railway signalling devices and systems - station and track signaling devices on the circuit of the model track in the management of train traffic under normal conditions • The students are able to operate the railway traffic according to the planning timetable	• Introduction • Systems safety • Controlled infrastructure elements • Block systems • Interlocking • Automatic Train Protection • Level crossings	• Lecture presentation • Selected chapters from the textbook 'Railway traffic operation. Basics of railway transport' resp. 'Railway traffic operation.' • Textbook 'Railway traffic operation. Transport laboratory exercises'	• Introductory lab session • Doing experimental work with the interlocking devices • Interlocking devices operation • Train traffic operation, standard operation of interlocking devices • Train traffic operation according to the timetable	• Moderated online session • Moderated online sessions with multimedia textbook support

Railway Laboratory exercise 1 (Railway Transport / Bachelor level)	Slovak	• To expand the practical knowledge from the operation of signaling devices • The students can explain the principles and operation of railway signalling systems. • The students can dispatch the train operation according to the timetable. • The students can solve the operation irregularities. • The students can operate the non-standard states of the interlocking devices. • The students can perform qualitative and quantitative assessments of railway operations and its infrastructural, safety and vehicle-related boundary conditions.	• Getting acquainted with the operation of station signaling equipment and track signaling equipment. • Traffic operation by telephone. • Traffic operation by reporting the expected departure. • Traffic operation with the support of an electronic traffic book • Operational traffic management during lockout activities • Traffic operation during stationary equipment failures • Operational traffic operation failures of station interlocking device, trackside signaling failures • Operational traffic operation malfunctions of signals • Operational traffic operation malfunctions of signals • Operational traffic operation during simulated delays of passenger trains	• Lecture presentation • Selected chapters from the textbook 'Railway traffic operation. Basics of railway transport' resp. 'Railway traffic operation.' • Textbook 'Railway traffic operation. Transport laboratory exercises'	• Introductory lab session • Doing normal operation of interlocking devices • Interlocking devices operate according to the timetable • Train traffic operation, non-standard operation of interlocking devices • Train traffic operation with irregularities	• Moderated online session • Moderated online sessions with multimedia textbook support

Laboratory Transport Exercise (Railway Transport / magister level)	Slovak	• To expand the practical knowledge from the operation of signaling devices • The students can explain the principles and operation of railway signaling systems. • The students can dispatch the train operation according to the timetable. • The students can solve the operation irregularities. • The students can operate the non-standard states of the interlocking devices. • The students can perform qualitative and quantitative assessments of railway operations and their infrastructural, safety, and vehicle-related boundary conditions. •	• Getting acquainted with the operation of station signaling equipment and track signaling equipment. • Traffic operation by telephone. • Traffic operation by reporting the expected departure. • Traffic operation with the support of an electronic traffic book • Operational traffic management during lockout activities • Operational traffic management during stationary equipment failures • Operational traffic operation failures of station interlocking device • Operational traffic management during trackside signaling failures • Operational traffic operation malfunctions of signals • Operational traffic operation malfunctions of signals • Operational traffic operation during simulated delays of passenger trains	• Lecture presentation • Selected chapters from the textbook 'Railway traffic operation. Basics of railway transport' resp. 'Railway traffic operation.' • Textbook 'Railway traffic operation. Transport laboratory exercises'	• Introductory lab session • Doing normal operation of interlocking devices • Interlocking devices operate according to the timetable • Train traffic operation, non-standard operation of interlocking devices • Train traffic operation with irregularities	• Moderated online session • Moderated online sessions with multimedia textbook support

Application of railway interlocking systems (Process management / magister level)	Slovak	• A closer acquaintance of students with the activities of specific security systems applied on the ŽSR network. The design solution for relay station security devices, and electronic switchboards. Automatic trackside signaling equipment. Crossing security devices • The students can explain the functionalities of the safety devices	• Relay interlocking type AŽD 71 - selection group, execution group, procedures, demonstration of activities and methods - digital selection - circuit solution and description, demonstration of activity and method of operation • Electronic device type AŽD ESA 11, type Starmon K2000 / Betamont ESB1 Demonstration of activity and method of operation • Automatic block AH 2000 - analysis of basic circuits • Automatic block type AŽD 88 - analysis of basic circuits operation • Level crossing device type AŽD 71 - analysis of the activity of basic circuits, demonstration of activity • Level crossing device type BUES 2000 - design solution and demonstration of activities • Excursion to the transport laboratory • Excursion in ŽSR railway stations • Control test	• Lecture presentation	• Exercise in the laboratory focused on the knowledge of safety device construction • Practical training in the operation of the station safety devices by a variety of construction types	• Moderated online session •

In the teaching process in the laboratory of UNIZA are used following textbooks:

- Railway traffic operation / Jozef Gašparík ... [et al.]. – 1st issue. - Žilina: University of Žilina, 2016. - 278 p., ISBN 978-80-554-1281-8
- Železničná dopravná prevádzka. Základy železničnej dopravy (in Slovak language) [Railway traffic operation. Basics of railway transport] / Jozef Gašparík, Peter Blaho, Dušan Lichner. - 1st issue. - Žilina: Žilinská univerzita, 2015. - 407 p., ISBN 978-80-554-0996-2
- Železničná dopravná prevádzka : laboratórny dopravný výcvik (in Slovak language) [Railway traffic operation. Transport laboratory exercises] / Jozef Gašparík ... [et al.]. - 1st issue. - Žilina: Žilinská univerzita, 2014. - 142 p., [AH učebnica - 10,17; AH príloha - 29,47] : obr., tab. + príl. 1 DVD. - ISBN 978-80-554-0824-8

5.2.1 Railway traffic operation, University of Žilina, 2016

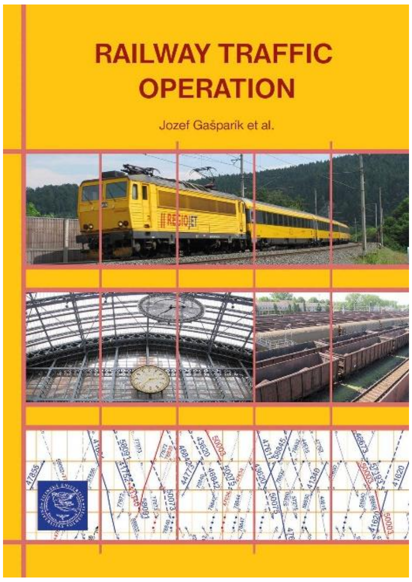

Fig. 27. Title page of book Railway Traffic Operation

The textbook provides a comprehensive summary of all railway transport aspects, from definition of railway network, to the design of railway tracks, characterisation and classification of rolling stock, safety equipment, rail traffic organisation, signalling specifications, principles of rail traffic management, and finally, service regulations and tools. On base of this knowledges the operational aspects of railway transport is developed. The timetabling and train formation are the main operational issues which are emphasised in the chapters.

The textbook is meant primarily for students of bachelor or master degree studies in the field of Traffic for the purposes of training the Rail Traffic Operation.

Study materials provide systematic overview of all rail traffic operation aspects, however it is not the textbook's objective to provide an extensive explanation and deal this wide-range issue in detailed manner. The textbook can, given its focus, equally serve to others intending to study railway traffic and provide them with a consistent view on traffic operation of railway. The operating parameters are in the textbook explained and focused on the conditions of Slovak Railways at all.

In teaching process in the laboratory, this text book serves to explain traffic management according to ŽSR regulations and explains signalling equipment, traffic regulations, as well as traffic documentation.

The content is in annex of this work.

5.2.2 Railway traffic operation. Basics of railway transport. University of Žilina, 2015

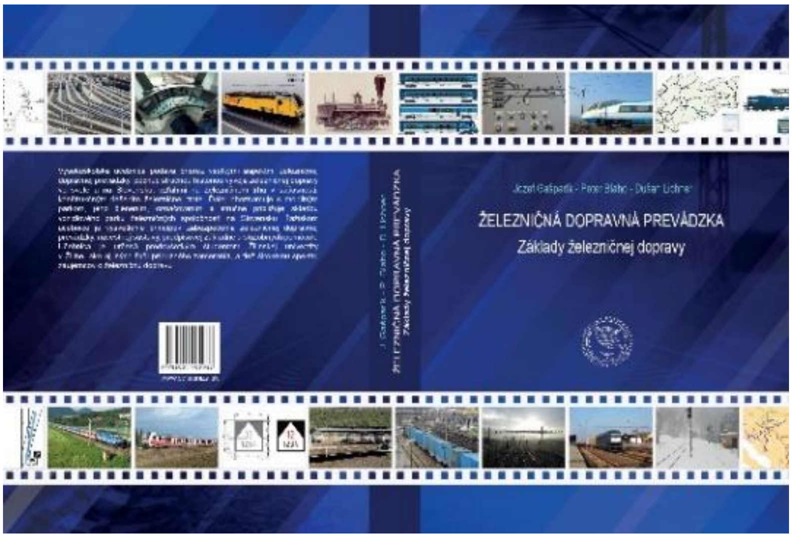

Fig. 28. Title page of book Železničná dopravná prevádzka – základy železničnej dopravy (note: book only in *Slovak language*)

The teaching textbook provides a cross-section of all aspects of railway transport, starting with a brief history of the development of railway transport in the world and in Slovakia, relations in the railway market at present, the design of the railway line. It also introduces the mobile fleet, its classification, marking and briefly describes the composition of the rolling stock of railway companies in Slovakia. The focus of the textbook is an explanation of the principles of operating railway traffic, signaling system, regulatory base and service aids. The textbook is intended primarily for students of the University of Žilina in Žilina, as well as other related universities, as well as a wide range of people interested in railway transport.

In teaching process in the laboratory, it serves to explain traffic operation according to ŽSR regulations and explains security devices, traffic regulations, as well as traffic documentation.

The content is in annex of this work.

5.2.3 Railway traffic operation. Transport laboratory exercises, University of Žilina, 2014

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Fig. 29. Title page of book Železničná dopravná prevádzka – Laboratórny dopravný výcvik (*note: book only in Slovak language*)

The university textbook provides a cross-section of all aspects of railway transport, The focus is on an explanation of the principles of securing railway traffic, signaling system, regulatory base, and service aids. The textbook is intended primarily for students of the University of Žilina in Žilina, as well as other related schools, as well as a wide range of people interested in railway transport. Teaching in the laboratory serves to explain traffic management according to ŽSR regulations and explains security equipment, traffic, and signaling regulations, as well as traffic documentation. The textbook is directly adapted to the conditions of operation in the transport laboratory. It contains a multimedia attachment on a DVD, which contains texts, images, and videos showing the operation of the equipment and traffic management in the laboratory.

The concrete content is in the annex of this work.

5.3 Laboratory of TU Braunschweig

Table 3 is an overview of the study programs and teaching subjects in the transport laboratory of TUBS. The content, teaching material, taught modules in the laboratory, and the replacement solution during the pandemic period also. 7

Table 3. Overview of subjects realized in the IfEV laboratory - TUBS

Module	Language	Educational objective	Contents	Teaching material	Use of the laboratory		Replacement solutions
					Interlocking simulator	Cab simulator	

							for the pandemic
Bahnsicherungstechnik (Railway signalling)	German	• The students can explain the fundamental elements and principles of railway signalling systems. • The students can select suitable techniques and processes for a planned application. • The students can apply planning principles in safety-related equipment planning	• Introduction • Systems safety • Controlled infrastructure elements • Block systems • Interlocking • Automatic Train Protection • Level crossings	• Lecture presentation • Selected chapters from the textbook 'Systemtechnik des Schienenverkehrs' • Offline simulation of one control district of the Signalsoft network to be used at home to prepare for lab sessions by self-study • Instructions and tutorial video for the Signalsoft user interface	• Introductory lab session with the Signalsoft network • Doing experimental work with the interlocking simulator guided by a task sheet	• Introductory run on the cab simulator • Experience signal aspects and different ATP systems by a simulator run	• Moderated online session with connecting interlocking simulations in multi-user mode • The moderated online session for doing experimental work with the interlocking simulator • Interactive cab run video
Railway Signalling Principles	English	• The students can explain the fundamental elements and principles of railway signalling systems. • The students can select suitable techniques and processes for a planned application. • The students can apply planning principles in safety-related equipment planning • The students can relate the impact of signalling systems on operational	• Basic terms and definitions • Controlled trackside elements • Block systems • Interlocking • Automatic Train Protection • Level crossings	• Lecture presentation • Open Access E-book 'Railway Signalling Principles' • Offline simulation of one control district of the Signalsoft network to be used at home to prepare for lab sessions by self-study • Instructions and tutorial video for the	• Introductory lab session with the Signalsoft network • Doing experimental work with the interlocking simulator guided by a task sheet •	• Introductory run on the cab simulator • Experience signal aspects and different ATP systems by a simulator run	• Moderated online session with connecting interlocking simulations in multi-user mode • The moderated online session for doing experimental work with the interlocking simulator

		capacity and traffic control procedures		Signalsoft user interface			• Interactive cab run video
Bahnbetrieb (Railway operations)	German	• The students acquire in-depth knowledge of the planning, management, and operational implementation of the operation of railways. • The students can evaluate the performance of railway operating systems. • The students can select suitable operating procedures and create timetable concepts. • The students can use IT-tools for investigating operational issues. • The students can perform qualitative and quantitative assessments of railway operations and their infrastructural, safety, and vehicle-related boundary conditions.	• Basics • Capacity management • Train path management • Train control principles • Marshalling yards	• Lecture presentation • Selected chapters from the textbook 'Systemtechnik des Schienenverkehrs' • Offline simulation of one control district of the Signalsoft network to be used at home to prepare for lab sessions by self-study • Instructions and tutorial video for the Signalsoft user interface	• Introductory lab session with the Signalsoft network • Real-time timetable test session for timetables previously established by FBS	-	• Moderated online session with connecting interlocking simulations in multi-user mode
Internationaler Bahnbetrieb und ETCS (International railway operations and ETCS)	German	• By conveying the characteristic features of foreign operating procedures, the students can recognize features that deviate from German principles.	• Specific operational and signaling features used outside of Germany • ETCS (levels, modes,	• Lecture presentation • E-book 'Besonderheiten ausländischer Eisenbahnbetriebsverfahren' (Springer Essential)	• Offline simulation at the home of the Wembley Suburban line (SimSig interlocking simulator) • Lab session with	• Cab simulator run to experience different ETCS levels including level transitions	• Moderated online session by connecting SimSig interlocking simulations in multi-user mode

		• The students can evaluate the relevance of characteristic features of foreign operating procedures and assess the possibilities and limits of harmonization. • The students can explain the functionalities of the European Train Control System (ETCS).	supervision curves) • Use case: Operations control in British Control Centres	• E-book 'Eine Einführung in das European Train Control System (ETCS)' (Springer Essential) • Instructions and tutorial video for the British user interface	controlling a British network (SimSig interlocking simulator) • Doing experimental work with the SimSig interlocking simulator guided by a task sheet		• Interactive cab run video
ÖPNV - Planung von Infrastruktur (Public transportation - Infrastructure planning) Chapter 7: Signalling for urban rail transit system	German	• The students can plan infrastructure systems for public transport (rail and road) in Germany according to the relevant procedures and rules for a specific application and to accompany the construction. • The students can select suitable safety systems for a planned application and dimension them operationally. • The students can perform basic safety-related equipment planning.	• Signalling principles for metro rail and LRT systems • Signalling principles for tram systems	• Lecture presentation • E-book 'Sicherungstechnik für Bahnen im Stadtverkehr' (Springer Essential) •	• Lab session on traffic control on the Cologne LRT network (Bahnsim simulation software with original user interfaces of the Cologne control centre))	-	-

6. THE PRACTICAL SKILLS FROM TEACHING IN TRANSPORT LABORATORIES

The goal of education in transport laboratories is to provide education intended for the practical management of railway transport operations. The graduate should have knowledge and skills in the conditions of operating railway transport on various types of security equipment.

At each level of operation management, the student should be able to manage the transport operations (passenger and freight transport) both operationally and legally (according to relevant regulations). The graduate should be able to manage transportation and technological processes, as well as (based on practical experience from laboratory training) establish basic business economic and operational activities.

The professional focus of the graduate is based on knowledge in the field of railway transport operations, as well as basic knowledge of the functionality of security devices for the future management of transport processes. The graduate should be able to evaluate the operational results of railway transport activities based on transport requirements and results in the field of human resources. After completing laboratory exercises, the graduate should be able to determine and describe technological and organizational procedures and technical-organizational measures.

The student can actively acquire information and use it to solve practical tasks in the field using usual research and development procedures, with a critical assessment of their appropriateness and adequacy. The graduate can present the range of transport services and propose alternative options for organizing transport processes for different types of clients. The graduate was able to bear responsibility for compliance with legal and technical regulations that traffic operations require. The acquired knowledge and skills will enable him to further develop his knowledge of theoretical disciplines. All knowledge is also developed from the point of view of economic and transport disciplines in transport. Knowledge regarding the requirements for human and financial resources necessary for the implementation of transport activities is an integral part.

All three universities involved in the Idealcarel project have their specific transport laboratories. The interlocking systems are installed in each laboratory, which is also used in normal transport operations on railways. Each transport laboratory uses national interlocking systems in different categories and designs.

Based on the acquired knowledge, competencies, and practical skills, the graduate will primarily apply to the lower and middle levels of railway transport management. Under the conditions of the Department of Railway Transport at the University of Žilina, the Cooperation with the Railways of the Slovak Republic (national infrastructure manager) has developed a specific program, where courses are held to acquire professional qualifications for the typical position of a ŽSR employee (the station dispatcher).

All interlocking systems meet the criteria that are set for the practical management of traffic operations in the given country (region).

However, the interoperability of the railway transport space requires knowledge not only in the field of traffic management at the national level but also knowledge of other systems. It is this knowledge that moves the so-called "employee value" to a qualitatively higher level. International experience in managing railway traffic operations is an important currency for the future employment of graduates in the labour market.

The pandemic period and online classes from 2020 have significantly limited practical education directly in laboratories. These limitations were used to make education more efficient in the online space, also with a link to education in transport laboratories. Their online connection and the subsequent interaction of students from home universities make it possible to expand their knowledge and skills significantly. The online space enabled the creation of international traffic management teams on specific interlocking systems. This creates a basic prerequisite for the interoperability of the railway transport space, not only from the point of view of the development of technics and technologies but also of the human potential intended for the management of transport processes.

Other, more specific, outputs of online education in transport laboratories can be added:

- competence to take measures to minimize the negative effects of international transport processes,
- competence in dealing with the energetics of driving rolling stock and its consequences on the economy of operation,
- competence in the coordination and management of the development of railway transport, in the classification of the infrastructure of individual types of transport in connection with the needs of individual requirements for transport,
- knowledge and competence in the field of technological, technical, and economic characteristics of individual technical and technological systems,
- • knowledge of vehicle mechanics, understanding traction characteristics of driving vehicles and shunting,
- • knowledge and competence in managing processes in transport operations, independently designing, and applying technological procedures, management and organization of operational activities diversified according to entities participating in

railway operations in the full complexity of the interoperability of the railway system according to the given configuration of interlocking systems, vehicle fleet and level of automation and control transport,

- • knowledge in constructing a chart of train traffic in compliance with technical and technological regulations,
- • skills in working with economic analyses and data with a focus on the railway market.

HANDBOOK FOR TRAINERS

The created handbook for trainers should prepare trainers and lecturers for online or hybrid academic exercises. This document should support the preparation and the exercise itself. A key issue for a successful online or remote exercise is the technical preparation, as technical problems or issues could delay or cancel the exercise. This handbook should prepare teachers and trainers for an online or hybrid exercise. The "Handbook for trainers" is a separate document that can be downloaded from the IDEALCAREL homepage. In addition, the manual is integrated into this IO on the following pages. This handbook is elaborated in a separate document and also attached

Purpose of this handbook and definitions

This handbook should prepare trainers and lecturers for online or hybrid academic exercises. This document should support the preparation and also the exercise itself. A key issue for a successful online or remote exercise is the technical preparation, as technical problems or issues could delay or cancel the exercise.

Before the start of the exercise it is also a key issue that students have a basic knowledge of the functions of the used interlockings. This knowledge should be gained before the exercise. This should be done with an introduction lecture and individual work at the interlockings.

- Distance exercise:

  An exercise what is hold entirely remotely e.g. online with a virtual railway laboratory or with laboratory where remote control is technical possible with no participants in the facility

- Hybrid exercise

  An exercise what is hold with groups in the laboratory and with online groups that are participating remotely.

TRAINING GUIDELINES FOR AN ONLINE AND HYBRID SESSION

The objective of an exercise is to gain practical skills and support the understanding of the learned knowledge of the lecture. Online and hybrid lectures are a new concept in the railway sector. For that reasons it is necessary that the trainers and the participants are preparing themselves well before the exercise. Because the preparation is a key issue for the success of the exercise.

It also necessary that the trainers and the participants to familiarise themselves with the applications and equipment used. The necessary information should be prepared in advance by the trainer and the trainer should prepare himself well for the exercise. It has also to be considered how many trainers should supervise the exercise. It could be very useful to split the tasks of the technical and didactical support. In that case one trainers will focus in

For a successful exercise it is important to choose the right software tools in advance. This includes the simulation tool of the interlocking and also the communication platform. The choice of the simulation depends on the goals of the exercise and what tool will is available in the institution. This guidelines are written as generic as possible and not for and for a specific software tool, hence it can be applied for almost every simulation.

Communication:

Nowadays there are a lot of communications platforms for videoconferences on the market. For that reason it is necessary to choose the platform in advance and that the participants are familiar with the platform.

The communication between the trainer, technical supporters and the participants is essential for a successful exercise. So it is necessary that everybody who is involved in the exercise prepares themselves to handle the communication platform. This includes the use and the functions of the communication tool. Furthermore the participants have also to prepare their hardware for the use of the communication platform.

The following steps are suggestion for a systematic approach to explain the communication platform:

- Choose a communication platform in advance
- Make sure, that the participants are familiar with the platform.
- Describe the software and their function precisely
    - How to log in and use the audio and camera
    - Where is the chat and how does it work
    - If you´ll work with bigger groups, then explain the break out rooms
- Inform the participants about the required hardware for the exercise

It is necessary that the participants understand the communication tool before the start of the exercise. This includes also the changes for checking audio- and video connection. The participants should check in advance also their function of their devices e.g. battery, headsets etc.

Two requirements are necessary for the used conference tool, this are screen sharing and remote control. The screen sharing is necessary for the participants, because if they have any difficulties by controlling the interlocking, then it is possible for the trainer to explain the problem. With the option of remote control it is possible for the trainer to show necessary steps or control options on the screen of the participant.

Technical preparation:

The technical preparation with the used software (to simulate the interlockings) is necessary, to secure a fluent exercise. If technical problems occur through the exercise a lot of time could be lost with solving the issues. If the a onside laboratory will be controlled remotely it is also a good advice to test the connections and prepare the devices of the participants

Generic steps in advance could be:

- For working on a network based simulation the participants, especially the host, it could be possible that participants need to know their IP-addresses and have to check the router settings, e.g. allowing port forwarding.
- Also a good advice about installation of the simulation software is needed e.g. with a short guideline written by the trainer
- For students who are not familiar with this issues, the trainer has to provide online assistance.
- All the issues should be checked before the online session starts
- Further steps based on the used software

The controlling of every software can be different, however this steps are generic, hence it is possible that the trainer follow this steps to prepare the participants for the exercise.

PREPARATION OF THE PARTICIPANTS:

The participants should know the basic functions of the used software and it´s interlockings before the exercise starts. Because the exercise should be a training of the connected railway operation and not about the basic functions of signaling principles. For the preparation first a common lecture concept can be used by explaining the software and basic functions by the trainers (hint: you can also use the generic introduction for controlling interlockings delivered by the IDEALCAREL project in IO3). Then the participants should work with the interlockings on a self-study base. This can be used in both hybrid and entire online concepts. The time of the self-study depends on the planned model of the exercise e.g. you can see use the template of the generic course developed in IO 3. In general it is necessary that the participants have understood the explained principles and basics of the interlockings to avoid basic questions which could delay the exercise.

Exercise:

The execution must support the objectives. So the whole concept of the exercise has to be checked by experts/trainers before the students will execute that training. So the trainer should check in advance:

- Is the timetable didactical useful?
- Are there all necessary movements covered that should be shown?

For the online exercise it is also necessary for the trainer to make sure that the participants understand the railway environment. So the trainer has to check in advance if the participants understand their actions on an electronic interlocking e.g. how does a signal aspect look at a signal or how look a Movement Authority in the DMI etc.

The used timetable depends on the knowledge of the students. For beginners the timetable should be designed with train movements, less shunting movements and no degraded mode operations. For more advanced students the timetable can be designed with train movements and more shunting processes and less degraded mode operations with small delays. For high advanced students the more degraded mode operations should be considered.

Level of the students	**Movements**	**Degraded mode operations**
Beginners	Train movements	No
Advanced	Train and shunting movements	Less
High Advanced	Train and shunting movements	High

Table 4. Table 1 Operational concept for the exercise based on the experience of the students

The trainer should prepare the timetable of the exercise and chose the right level of the exercise in advance.

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Debriefing of the exercise:

A debriefing after the exercise can provide feedback to the participants and analyse the lessons learned. Furthermore the strength and weakness of the railway operation can be analysed. Hence the trainer should take notes during the exercise and give feedback about the points that worked well and also about the mistakes.

The outcome of the Debriefing has to be remarked in the next version of the documentation and in the future of the next

The following questions can be an example/guideline of how structure a questionnaire can be prepared. This concept was also used during the IDEALCAREL project to get feedback from the students that participated in the test. Furthermore the same questions were asked to the trainers. Hence, it is also possible to use the questions for the self-assessment of the trainers to improve the exercise. The first question is about the place of study, this is only necessary if you work groups from different universities. However, the question could also be asked to determine the degree of education of the students, e.g. Bachelor or Master. The question 2 to 5 are question to rate the activities. 5 to 8 are simple yes or no answers and the last questions are open-ended questions to get broader feedback.

1. Current place of study:
2. How would you rate the activities of the introduction lecture? (1- worst – 5 best)
    a. Lectures
    b. Teaching and learning session
    c. Teaching materials (e.g. handouts, slides)
    d. I improved my knowledge
    e. My satisfaction is
3. How would you rate the activities of the individual work days (08.12.2022)? (1- worst – 5 best)
    a. Lectures
    b. Teaching and learning session
    c. Teaching materials (e.g. handouts, slides)
    d. I improved my knowledge
    e. I was happy with support my group received from supervisors
    f. My satisfaction is
4. How would you rate the activities of the connected exercises (09.12.2022)? (1- worst – 5 best)
    a. Lectures
    b. Teaching and learning session

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   c. Teaching materials (e.g. handouts, slides)
   d. I improved my knowledge
   e. I was happy with support my group received from supervisors
   f. My satisfaction is
5. The online testing helped me to improve my language skills. (Yes or No)
6. The online testing helped me to improve my communication skills. (Yes or No)
7. Teamwork helped me to understand better learning process. (Yes or No)
8. Teamwork helped me to understand other students better. (Yes or No)
9. Overall, what was good about online testing? (Open-ended question)
10. Overall, what was bad about online testing? (Open-ended question)

Institut für Eisenbahnwesen und Verkehrssicherung IfEV TU Braunschweig

ŽILINSKÁ UNIVERZITA V ŽILINE
Fakulta prevádzky a ekonomiky dopravy a spojov

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IDEALCAREL

ANNEX: CONTENT OF STUDY MATERIALS (BOOKS):

Railway traffic operation, University of Žilina, 2016

1. RAILWAY MARKET
1.1. Production process in trasportation
1.2. Relations in the transport market
1.3. European transport policy
1.4. Transformation Process of Unitary Railways in Slovakia
1.5. Basic Terms
2. RAILWAY NETWORK
2.1. Railway network definition
2.2. Railway line
2.3. Operating control points
2.4. Posts
3. TRACK LINE DESIGN
3.1. Railway substructure
3.2. Railway superstructure
3.3. Other facilities of the railyard
3.4. Line class and structure gauge
4. ROLLING STOCK
4.1. Major rolling stock constituent parts
4.2. Braking system and train braking
4.3. Classification of rolling stock
4.4. Trailer vehicles
4.5. Marking of rolling stock
5. RAIL SIGNALLING SYSTEM
5.1. Signal aspects on rail signal devices
5.2. Marking of fixed rail signal devices
5.3. Other Fixed signal devices and signals for rail vehicles movement
6. SAFETY DEVICES AND TELECOMMUNICATIONS
6.1. Station safety devices
6.2. Line safety devices
6.3. Train safety devices
6.4. Level crossing safety devices
6.5. Information and communication railway devices
7. TRAFFIC MANAGEMENT IN RAILWAY TRANSPORT

7.1. Rail traffic operation
7.2. Train definition
7.3. Ensuring the train movement
7.4. Transport services operation and service documentation
8. LOCAL PROCESSES AND TRAIN FORMATION
8.1. Model of wagon flow organization and components of train forming plan
8.2. Technological process in railway stations
9. TRAIN TRAFFIC DIAGRAM
9.1. Graphic presentation of train traffic diagrams
9.2. Classification of train traffic diagrams by their types
9.3. Data for compiling train traffic diagrams
10. ESTIMATION OF RAILWAY INFRASTRUCTURE CAPACITY
10.1. Essential terms and types of throughput efficiency
10.2. Essential principles and methodologies for measurement of throughput and capacity
10.3. estimation infrastructure capacity by using the simulation tools
10.4. International cooperation in timetabling

Basics of railway transport. University of Žilina, 2015

1. BRIEF OVERVIEW OF THE HISTORY OF RAILWAY TRANSPORT
2. THE RAILWAY MARKET
2.1. Relations in the market for transport services
2.2. European transport policy
2.3. Transformation of railways in Slovakia
2.4. Interoperability of European Community railways
3. RAIL NETWORK
3.1. Definition of the rail network
3.2. Railway network in Slovakia
3.3. Interesting facts of the ŽSR railway network
3.4. Railway line
3.5. Transport
3.6. Stations
3.7. Railway stations
4. RAILWAY STRUCTURE
4.1. Railway classification
4.2. Railway undercarriage
4.3. Railway superstructure
4.4. Line class and Cross section

Transport laboratory exercises, University of Žilina, 2014

Printed part

1. The importance of teaching railway traffic in a specialized classroom
2. Characteristics of the KŽD ŽU transport laboratory
3. Characteristics of security devices
4. Railway traffic management
5. Train traffic schedule
6. Software tools to support traffic management

Electronic part

1. Characteristics of the transport laboratory

1.1. Hričov station

1.2. Žilina station

1.3. Púchov station

1.4. Vrútky station

1.5. Bytča station

1.6. Track-side signaling equipment

2. Operation of station security equipment
3. Operation of track signaling equipment
4. Signal system on the railway
5. Train traffic schedule and service documentation in the transport laboratory
6. Traffic management in the transport laboratory
7. Management of railway traffic in case of breakdowns and emergencies
8. Transport documentation
9. Dictionary of technical terms of railway transport operation

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