**“Traffic Management and Scheduling for Railways”**

**Syllabus SCR.05a/3**

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Version 1

# Name of the course

**Traffic Management and Scheduling for Railways**

# ECTS credits

6 Credits, (**45 hours of Theory + 45 hours of Exercises & Lab**)

# Objectives

The aim of the course is to learn the theoretical and practical aspects of railway traffic engineering. The aim of the course is to familiarize the student with principles of railway traffic on the railway network and shunting. Students learn the basic concepts of railway traffic management and organization of the transport process. The student learn about elements of the railway network, basics of working technology of the railway station and principles of railway signalling and railway traffic control systems, with particular emphasis on the European Railway Traffic Management System (ERTMS). The student is familiar with principles of designing of railway infrastructure taking into account the requirements of railway traffic engineering. The basic principles for calculating of the movement resistance as well as a cappacity problems of railway lines are discussed. The purpose and ways of implementation of the ERTMS are presented.

Overall, the lecture provides students with a solid foundation for the design of railway infrastructure, and above all planning (timetables) and traffic control (for example, bandwidth management and delays). The experience gained by students is then used in real-life traffic scenarios.

# Learning outcomes

The general expectation regarding the knowledge to be provided/acquired is as follows:

* To familiarize students with the concepts of railway traffic technology.
* To familiarize students with the rules of railway traffic.
* Understanding the procedures related to the operation of railway infrastructure.
* Awareness of the impact of professional and personal competences on the efficiency and safety of traffic.
* Providing students with knowledge in the field of railway traffic engineering in the context of other transport systems.
* Ability to define the concepts related to running the railway traffic using modern audiovisual techniques.
* ability to define priorities of transport tasks in rail transport
* Mastering the tools / instruments for planning and managing timetables, taking into account the needs of users of transport processes and services that can be shared with them
* To familiarize students with the basic principles of running trains on the routes, methods of determining the forces acting on the train and principles of drawing up traffic charts, and also has knowledge about the methods of assessing the capacity of lines and railway stations.
* To familiarize students with the methods of arranging timetables for a section of a railway line and a railway junction

# Contents

1. **Basic Characteristics of Railway Systems and the Requirements for Signalling**
   1. Introduction
   2. Specific of Railway Systems
   3. Railway Signalling and Control
      1. Definitions
      2. The Safety-related Railway Theory
      3. Functional Structure
2. **Railway Operation**
   1. Historical Background
   2. Classification of Tracks, Stations and Signals
      1. Main Tracks and Secondary Tracks
      2. The Role of Signals
      3. Definitions of Stations and Interlocking Areas
      4. Signal Arrangement on Double Track Lines
   3. Movements with Railway Vehicles
      1. Train Movements
      2. Shunting Movements
   4. Principles of Train Separation
      1. Signalled Fixed Block Operation
      2. Cab Signal Operation
      3. Non Signal-controlled Operation
   5. Dispatching Principles
      1. Decentralised Operation
      2. Centralised Traffic Control
3. **Interlocking Principles**
   1. Overview
      1. Introduction
      2. Basic Requirements
      3. Basic Principles of Safeguarding a Train’s Path
   2. Element Dependences
      1. Classification
      2. Coupled Elements
      3. Unidirectional Locking
      4. Simple Bidirectional Locking
      5. Conditional Bidirectional Locking
   3. Routes
      1. Introduction
      2. Extension of Routes and Related Speed Restrictions
      3. Basic Route Locking Functions
      4. Route Selection by the Signaller or Automatic System
      5. Flank Protection
      6. Overlaps and Front Protection
      7. Route Elements in the Start Zone
      8. Life Cycle of Routes
      9. Principles of Route Formation in the Track Layout
      10. Shunting Routes
      11. Automation of Route Operation
   4. Block Dependences
      1. Introduction
      2. Geographical Assignment of Block Sections
      3. Classification of Block Systems
   5. Special Issues
      1. Overlaying Block and Route Interlocking Systems
      2. Protection of Trains by a Signal at Stop in Rear
      3. Several Trains between two Signals
      4. Degraded Mode Operation
4. **Detection**
   1. Requirements and Methods of Detection
      1. Introduction
      2. Types of Objects
      3. Safety Requirements
      4. Detection Purposes
   2. Requirements and Methods of Detection
      1. Classification
      2. Spot Wheel Detectors
      3. Linear Wheel and Axle Detectors
      4. Area Detectors for Vehicles and External Objects
      5. Three-Dimensional Detection
      6. Systems with Active Reporting from the Train
      7. End of Train (EOT) Detection Systems
   3. Track Circuits
      1. Basic Structure of Track Circuits
      2. Geometrical Assembly of Track Circuits
      3. Treatment of Traction Return Currents
      4. Additional Functions of Track Circuits
      5. Immunity against Foreign Currents
      6. Electrical Parameters and Dimensioning
      7. Application of the Types of Track Circuits
   4. Axle Counters
      1. General Structure and Functioning
      2. The Rail Contact
      3. Treatment of Counting Errors
   5. Comparison of Track Circuits and Axle Counters
      1. Advantages and Disadvantages
      2. Application
5. **Signals**
   1. Requirements and Basic Classification
   2. Technical Characteristics of Trackside Signals
      1. Structure of Light Signals
      2. Optical Parameters
      3. Retro-Reflection of Passive Signal Boards
      4. Control and Supervision of Signal Lamps
   3. Principles of Signalling by Light Signals
      1. Utilisation of Signal Colours
      2. Stop Aspects
      3. Signalling of Movement Authorities
      4. Signalling of Speed Reductions
      5. Combination of Main and Distant Signals
      6. Shunting Signals
6. **Train Protection**
   1. Requirements, Classification and Conditions for Application
      1. General Overview
      2. Cab Signalling Functions
      3. Supervision Functions
      4. Intervention Functions
      5. Role in the Railway Operation Process
      6. Automation of Train Operation
   2. Technical Solutions for Data Transmission
      1. Overview over Forms of Transmission
      2. Spot Transmission
      3. Linear Transmission
   3. Particular Systems
      1. Classification of Systems
   4. ETCS
      1. History + Motivation
      2. Application Levels and Technical Components
      3. Functional Concepts
      4. Operation Modes
      5. Data Structure
7. **Interlocking Machines**
   1. Classification
   2. Mechanical Interlocking
      1. Historical Development
      2. System Safety in Mechanical Interlocking
      3. Structure of Mechanical Interlocking Systems
   3. Relay Interlocking
      1. Historical Development
      2. System Safety in Relay Interlocking
      3. Design of Relay Interlocking Systems
   4. Electronic Interlocking
      1. Historical Development
      2. System Safety in Electronic Interlocking
      3. Structure of Electronic Interlocking Systems
   5. Hybrid Technologies
      1. Hybrid Mechanical and Electrical/Pneumatic/Hydraulic Forms
      2. Hybrid Relay and Electronic Forms
8. **Line Block Systems**
   1. Classification
   2. Safety Overlays for Systems with Safety Responsibility at Staff
   3. Decentralised Block Systems
      1. Overview
      2. Token Block Systems
      3. Systems with Singular Unblocking upon Clearing
      4. Systems with Continuous Unblocking
   4. Centralised Systems for Safety on Open Lines
      1. Overview
      2. Centralised Block Systems for Secondary Lines
      3. Radio Electronic Token Block
      4. Open Line Controlled from Neighbouring Interlockings
      5. Train Control Systems for High Speed Lines
   5. Moving Block Systems
9. **Remote Control and Operation Technology**
   1. Remote Control and Monitoring
      1. Types of Dispatcher Control/Monitoring
      2. Centralisation of Interlocking Control
      3. Flexible Allocation of Control Areas
   2. Processes in Operation Control
      1. Information Input and its Viewing
      2. Evaluation of Operational Situation
      3. Command Output
   3. Data Transmission in Remote Control Systems
10. **Safety and Control of Marshalling Yards**
    1. Principles of Marshalling of Trains
    2. Parts of Marshalling Yards and their Function
       1. General Structure and Functioning
       2. Layout Variants
       3. Automation
    3. Control of Marshalling Yards
       1. Introduction
       2. Retarders
       3. Handling Systems for Freight Wagons
       4. Points
       5. Sensors
       6. Track Clear Detection
       7. Yard Management Systems
11. **Level Crossings**
    1. Requirements and Basic Classification
    2. Static Roadside Signs
    3. Passive Level Crossings
    4. Active Level Crossings
       1. Overview
       2. Dynamic Roadside Safeguarding
       3. Opening and Closing of Level Crossings
       4. Supervision of Level Crossings
       5. Possibilities of Degraded Mode Operation
       6. Combination with Road Junctions
    5. Removal of Level Crossings
12. **Hazard Alert Systems**
    1. Hazards in Railway Systems
       1. Safety Related Hazards
       2. Security Related Hazards
13. **Timetable Design Principles**
    1. The Purpose of Scheduling
    2. Basic Terms of Railway Operation
    3. Diagramming Traffic
    4. Scheduled Running Time
    5. Modelling Train Paths
       1. Principles of Train Separation
       2. Application of the Blocking Time Model
       3. Modelling Specific Signalling Systems
       4. Modelling Interlockings and Overlaps
       5. Stochastic Blocking Times
       6. An Alternative Approach: The Protected Zone Model
    6. Headways and Buffer Times
    7. Consumed Capacity
    8. Scheduling Methods
       1. Manual Scheduling
       2. Computer-based Scheduling
    9. Cyclic Timetables
14. **Infrastructure Modelling**
    1. Introduction
    2. Graph Theory and its Application
    3. Macroscopic Models
    4. Microscopic Models
    5. Differences between Infrastructure Models
    6. Migration between Infrastructure Models
    7. Application of Infrastructure Models
    8. Outlook
15. **Running Time Estimation**
    1. Introduction
       1. Fundamentals
       2. Speed Profile
    2. Infrastructure and Train Data
    3. Moving Sections
    4. Modelling Running Time Calculations
    5. Solving the Differential Equations by a Difference Equation Approach
    6. Solving the Differential Equations Analytically
    7. Solving the Differential Equations by Gauss Quadrature Integral Formulae
    8. A Probabilistic Approach
    9. Calculating Blocking Times
16. **Energy-Efficient Railway Operation**
    1. Minimisation of Mechanical Energy Consumption
    2. Optimisation under Practical Billing Systems
    3. Measures to Introduce Energy-Efficient Driving
17. **Queueing**
    1. Introduction and motivation
    2. Scheduled waiting times
       1. Scheduled waiting times on railway lines
       2. Scheduled waiting times at railway nodes
       3. Set of tracks as multiple server queues
    3. Estimating knock-on delays
18. **Timetable Stability Analysis**
    1. Introduction
    2. Stability
    3. Critical Circuit Analysis
    4. Recovery Time Analysis
    5. Delay Propagation
    6. Stochastic systems
19. **Optimisation Models for Railway Timetabling**
    1. Introduction
    2. Cyclic Timetabling
    3. Non-cyclic Timetabling
    4. Robust timetabling
20. **Simulation**
    1. Introduction – the role of simulation
    2. Methods of simulation
    3. Research and development
    4. Commercial software
    5. Simulation in practice
    6. Limitations and areas for development of microscopic simulation
    7. Conclusions

# Teaching method

**Lectures, Case studies, Tutorials/exercises, ITS architecture creating with the FRAME Architecture tools.**

* The slides are available for the whole lecture. These slides are must be provided to students (or must be uploaded in the MOODLE system). The full content of each slide is systematically explained by the Lecturer. Additional examples which are not included in slides will be proposed by the Lecturer to allow good understanding of the information provided.
* The slides contain exercises with solutions for the good understanding of the content of each chapter. These solutions are systematically explained (during the lecture) by the Lecturer.
* The Slides contain exercises without solutions to be solved by students during the lecture (this is part of oral exam). The students are fully assisted by the Lecturer in order to obtain correct/exact solutions to the proposed exercises. This will help to check whether the students have understood the chapters or not.
* Several exercises will be proposed by the Lecturer to be solved by students as projects. This will help to test the self-learning potential of students.

# Assessment method

Mid-term and final oral and/or written examination, exercises from case studies.

# Textbooks - Publications - Software

**Textbooks**

* Theeg Gregor, Vlasenko Sergej, Railway Signalling & Interlocking: International Compendium, PMC Media House GmbH, 2017
* Hansen Ingo A., Pachl Jorn (Red.), Railway Timetabling & Operations, PMC Media House GmbH, 2014
* Stanley Peter, ETCS for Engineers, PMC Media House GmbH, 2011
* Bonnett Clifford F., Practical Railway Engineering (2nd Edition), Imperial College Press

**Selected relevant Publications**

**Journals**

* IEEE TRANSACTIONS ON INTELLIGENT TRANSPORTATION SYSTEMS, IEEE
* TRANPORTATION RESEARCH, PART C: EMERGING TECHNOLOGIES, PERGAMON-ELSEVIER SCIENCE LTD
* JOURNAL OF INTELLIGENT TRANSPORTATION SYSTEMS, TAYLOR & FRANCIS INC
* INTERNATIONAL JOURNAL OF VEHICLE INFORMATION AND COMMUNICATION SYSTEMS, INDERSCIENCE ENTERPRISES
* IEEE TRANSACTIONS ON VEHICULAR TECHNOLOGY, IEEE

Software