TOPICS OF COURSES FOR FINAL STATE EXAMINATIONS

FOR STUDENTS AT FACULTY OF TRANSPORTATION SCIENCES CTU IN PRAGUE

N1041A040006 – INTELLIGENT TRANSPORT SYSTEMS

(valid from 1. 1. 2022)

I. COMPULSORY COURSE INTELLIGENT TRANSPORT SYSTEMS AND ITS COMPONENTS

1. Transport telematics - definition of transport telematics, legislative documents and standardization in the field of transport telematics;
2. General characteristics of telematics systems, architectures of telematics systems, hierarchical structure;
3. Applications and systems of transport telematics at the urban and national level - the most important examples of systems and their description;
4. Telecommunication technologies in transport telematics - examples of basic telecommunication standards used in transport telematics, their use;
5. Process of design and evaluation of telematics systems;
6. Basic tasks of urban engineering - basic definition of urban engineering, application in the city, types of documentation, engineering activities;
7. Urban growth and development - what cities need for their growth, public infrastructure, urban development requirements, basic needs of the population - explanations and examples;
8. Storage of technical infrastructure - types of public infrastructure of storage in street space - explanations, examples, requirements for public networks;
9. Requirements for urban engineering design - application of new trends, urban consideration, types of documentation and their approval, coordination situation, engineering, zoning plan;
10. Public transport terminal systems - examples, use, basic parameters, description of standards and requirements for public transport terminals, selection of locations;
11. Requirements for the design of infrastructure networks - storage, types of networks, requirements for public lighting, requirements with procedures for approval of documentation and their types;
12. Traffic surveys and simulations - use of traffic data, data interpretation, data processing, application of simulation methods for micro simulation, meso simulation, macro simulation, including advantages and disadvantages;
13. Incorporation of ITS systems into the formation of urban engineering - parking systems, toll system, public transport preferences (C-ITS, GNNS, types of preferences) - use, design;
14. Tunnel systems and applications in the city - hierarchy in the city, methods of construction, use, categorization of systems in the tunnel, application of ITS, requirements for infrastructures and networks;
15. Intelligent lighting - principles, use, advantages / disadvantages, application in urban planning, connection to new ITS trends, necessary infrastructure - networks, lighting calculations, lighting distribution, interfaces, installation of sensors;
16. Traffic management on motorways, agglomerations and main routes of the city related to urban engineering - basic requirements for design, connection to infrastructure and networking advantages / disadvantages, application of new approaches in designs;
17. Application of BIM in the design of ITS systems and transport infrastructure - project process, information standards, levels of application, use, entry conditions, advantages / disadvantages;

18. Application of the Digital Twin in infrastructure and ITS design in urban and rural areas, differences with the use of BIM, examples of application in urban engineering;
19. Examples of project design in the city on main and secondary roads - differences in the application of ITS from an urban perspective - infrastructure, documentation, scope, design and placement of signage, navigation and other systems.

II. COMPULSORY COURSE VEHICLE AND COOPERATIVE SYSTEMS

1. Cooperative systems and its principles, its benefits in traffic safety, C-ITS stakeholders;
2. Fundamental C-ITS components necessary for its operation, their architecture and principles;
3. Types of C-ITS messages, their content and principles, example of their usage;
4. C-ITS use-cases for Day-1 services description, their principles and triggers, end users;
5. Wireless technologies used in C-ITS; their technical parameters, functional properties, their comparison;
6. Radio solution based on the IEEE 802.11p standard, its principles and position in the ITS-G5 layer architecture;
7. DCC (Decentralized Congestion Control) principles in ITS-G5, possibility of priority parameter usage;
8. EDCA (Enhanced Distributed Channel Access) principles, the role of priority, the relationship between the number of shared users, latency and channel transmission capacity;
9. Coexistence of C-ITS based on IEEE 802.11p with toll systems using 5.8 GHz DSRC microwave technology;
10. The role of public mobile data technologies in C-ITS telecommunications solutions according to mobile service generations, 5G expectations;
11. LTE-V solution (according to 3GPP, Release 14 V2X communication), movement speed tolerance, two network control modes (3 and 4);
12. Benefits of 5G (3GPP, Release 15+) in the new features of C2X solutions;
13. Development possibilities of hybrid V2X communication solutions (e.g. ITS G5, LTE-V and eMBMS);
14. C-ITS security solution, architecture, key components, their properties and basic parameters;
15. Legal regulation of C-ITS, protection of personal data and possibilities of their protection in the whole ecosystem;
16. Product development process - Basic processes/phases of product development. Planning and concept phase of product development. Prototyping and testing phase of product development. Implementation phase of product development. Pilot series, zero series, SOP;
17. Quality methods - Quality methods used in the product development phase, quality methods in production, quality tools for monitoring customer satisfaction and monitoring the occurrence of defects in customers (NCBS, IACS, IAC, Costumer Insights = Censydiam Ad hoc Research...) Methods for implementing customer requirements (Questionnaire studies, group discussions, QFD). Methods to ensure the prevention of errors/faults (K-FMEA, P-FMEA), Methods aimed at cost savings (DFx = DFM, DFA, DFS, DFE) Supporting methods (statistical calculations, tolerance evaluation ...), FMEA and its types, reason for using FMEA;
18. Pre-Development - Defining the sales markets and analyzing them with respect to customer requirements, identifying key competitors, creating and presenting exterior/interior design models, product package, creating a conceptual description and technical description of the vehicle, powertrain design and combination, development costs and project capacity;

19. Testing - The role of experimentation in the product development phase, DoE (Design of Experiment), types of tests, importance and examples of tests, functional tests and their breakdown, durability tests and their breakdown, practical examples;
20. Test tracks - Definition of the tracks where the experiment will be carried out, reasons for unifying the tracks. Computer models of real tracks, reasons for their creation, examples of their use, catalogue of real tracks and models, concrete examples;
21. Important test laboratories - HIL - (HW in the Loop), HMI (Human Machine Interaction) - HMI testing methods and techniques. Types of simulators, selection of probands, design elements related to HMI, HMI test outputs. Dynamic Test Bed - Equipment testing, fatigue limit, low cycle fatigue, force transducers, trajectories, acceleration, loading method;
22. Safe and intelligent vehicle - Main factors of transport systems and their description, automation levels and their definition examples of vehicle assistance systems for each automation level. Systems - Intelligent traffic lights, Speed limit, Working zone warning, eCall, Post crash warning, Right of way violation, Autonomous ride, Wrong way driver, Road condition, Real time traffic inf., etc.;
23. ADAS: Advanced driver assistant systems - definition and objectives of ADAS, main ADAS systems and their functions (ACC, Lane departure Warning, Blind Spot Detection, Anti-collision system, Traffic jam assistance, Driver fatigue monitoring, Platooning, Parking assistance, Car-To-Hotspot, Car-To-Home, etc.);
24. Sensors supporting ADAS - Radars, cameras, on-board sensors, GPS, telecommunication technologies, V2V, V2I, etc.;
25. Active and passive safety systems, integrated safety - definition and elements of active and passive safety, driver errors and their elimination by driver assistance systems;
26. Driver fatigue monitoring - the issue of driver fatigue and how it can be detected (driver reaction, physical symptoms, etc.), vehicle reaction when fatigue/microsleep is detected;
27. Security and protection of vehicle systems against unauthorized interference - Cyber security and its solution in the vehicle, cyber security objectives. Functional security and its objectives. Cyber and functional security legislation;
28. Vehicle parking systems - types of systems, principle of operation and their support during parking, detection of obstacles around the vehicle;
29. Eyetracking - Methodology for objective evaluation of human gaze concentration. Possibilities and principles of human gaze tracking, types of eyetrackers, interior and exterior use, applications. Examples of eyetracking applications for vehicles and drivers.

III. ELECTIVE COURSE

(the student opts for one of the following elective courses)

A. SAFETY OF TRANSPORT SYSTEMS

1. Basic terms - reliability, safety, diagnostics, failure, predictive diagnostics of systems, failure-free operation, durability, repairability, readiness, etc.;
2. Diagnostic system - basic scheme of diagnostic systems, structural scheme of diagnostic system, functional and technical diagnostics;
3. Detailed division of individual diagnostic systems - classification of diagnostic systems, difference between station and on-board diagnostic system, difference between complex and distributed diagnostic system, examples of special diagnostic system;
4. Description of subsystems to the diagnostic system - fault localization, system model, principle of diagnostic model design procedures, determination of the technical state of the diagnosed system, measurement of quantities in diagnostics, forecasting methods;

5. Faults - types of faults, structure of the system in terms of fault investigation, explain the difference between accident and degradation, including examples of degradation;
6. Risk analysis - principle, function, types of risks and examples of distribution, matrix notation;
7. Functional safety - SIL, SIRF method - principle, block diagrams - RBD - serial and parallel, inductive and deductive approaches;
8. FTA fault trees - principle of use, advantages, disadvantages, event tree analysis - ETA - principle, advantages, disadvantages;
9. Analysis of failure modes and consequences - FMEA and FMECA - principle, use, advantages, disadvantages;
10. Faults by period, fault intensity, fault probabilities, fault-free operation probabilities and fault probability densities;
11. Areas of system investigation - area of acceptability, area of tolerances, area of availability, area of scrap, trajectories of life, lifetimes of systems, open and closed system;
12. Optimization of production yield with respect to production and operating prices, system parameter correction, shallow, deep, life line predictions;
13. Human-machine interaction - basic requirements for the operator or dispatchers, intrusion of attention drop, detection of attention drop;
14. Neuron - biological and mathematical description and functions, neural networks - types, basic description, use, applications;
15. System feedback and dynamic responses and signal stability - system stability and instability, use of controllers and control methods, knowledge and rule system, adaptive control method;
16. Application of Laplace transform in control, signal responses - jump, impulse, Nyquist stability criterion, linear and nonlinear systems;
17. Examples of failures and degradations in tunnel systems - legislation for major inspections of tunnel constructions, descriptions and revisions, classification, coverage in the tunnel, examples for system repairs;
18. Use of PLC for system control and security - principle and use of SCADA systems for process control, web access, setup and cybersecurity;
19. Application of the principle of safety management on railways - 4 phases of risk management applied in the safety management process, quantitative and qualitative methods of risk analysis, definition of the "fail-safe" principle;
20. Use of RAMS on railways, the difference between the principle of internal and external (redundant) safety, the technique of diversified software design;

B. GEOGRAPHICAL, LOCALIZATION AND NAVIGATION SYSTEMS

1. Basics of geographic information systems (GIS) - main functions, technologies, etc.
2. GIS model and GIS modeling - steps in the modeling process, examples of different types of models;
3. Basics of map projection in the system of country coordinates;
4. Raster and vector data - difference;
5. Basic graphic components of spatial data in GIS, the relationship between the GIS system and the database system, ways of working with the table of attributes;
6. Topological data model for a class of linear elements - principle and meaning;
7. Meaning of the following terms and abbreviations and how you are familiar with the concepts that include the specific use of these terms and abbreviations in the context of GIS: GPS, DGPS, vector data, geodatabases, raster data, TIN, DEM, DRG, spatial references, geographical and

projected coordinates, spheroid, WGS 84, attribute table, topology, data survey vs. data analysis, queries;

8. Minimum number of GPS satellites needed to determine the position of the receiver - explanation of the principle;
9. Basic principles and functions of the Global Navigation Satellite System (GNSS). What are "ephemeris" and what is "almanac";
10. GPS location in space - number of active satellites, number of satellites visible at one time;
11. What is DGPS (Differential GPS) - function and principle;
12. Structure of WAAS (Wide Area Augmentation System) - principle and purpose of the system;
13. Satellite signals and GPS codes (navigation message structure, transmission channels and their types);
14. GPS accuracy (civil vs. military use - knowledge of differences);
15. Use of location and navigation data in real time and after reprocessing - examples of use in both approaches;
16. PDOP (Positional Dilution of Precision) application, principle, examples;
17. GPS trilateration - principle, use in navigation and location systems, connection with triangulation;
18. Constellation 3Di as "GPS for indoor use" - principle and use;
19. Sources of GPS errors and their consequences - examples of possible errors.

C. TRAFFIC FLOW THEORY

1. Traffic flow - definition of traffic flow, influencing factors, basic properties of traffic flow, analogous processes in areas outside transport, relation to network industries, relation to spatial planning, relation to mobility, safety aspects;
2. Basic traffic quantities - definition of basic parameters (intensity, density, speed, distance, travel time, detector occupancy), individual and average values, hourly and daily values, point and section values and their mutual relation, relation to Lt diagram, meaning occupancy, the relationship between occupancy and density, the possibility of theoretical and practical measurements, calculations independent of the method of measurement, traffic variations;
3. Basic characteristics of vehicles, drivers and pedestrians - kinematics of movement, visual characteristics, reaction time, the effect of alcohol, rubbernecking effect;
4. Measurement of traffic parameters - methods of automatic measurement on infrastructure and in vehicles, role of traffic surveys, relation of measurement to Lt model, measurable quantities, range, advantages-disadvantages, intrusive and non-intrusive method of measurement, active and passive measurement, use of measured values, physical and technological properties and principles of measurement, configuration and properties of meters, the relationship between measurement configuration and measurable values;
5. Special measurements related to traffic flow - measurement of OD relationships, identification of vehicles or traffic participants, identification of traffic signs, pedestrian detection, detection of other traffic participants, detection of driving space, obstacle detection, measurement of weather conditions for traffic, measurement of car park occupancy, weight measurement vehicles, measurement of vehicle dimensions, measurement of vehicle categories, measurement of position and movement of objects in transport, detection necessary for preference of selected modes of transport, measurement of specific types of vehicles, measurement of vehicle occupancy;
6. Transport models in general - use of individual categories of models according to the level of detail, modeling principle, methods of model tuning, use of multi-mode and generalized models,

real and historical model, relation to traffic simulations at all levels of detail, quantities entered into simulations, simulation outputs, examples model applications;

7. Statistical models of transport - meaning of models, input and output quantities, basic statistical quantities (average, median, variance, etc.), discrete and continuous distributions of transport parameters, applications to various measured quantities - basic mathematical relations, parameters and limits of models, graphic statements, examples of applications and use of models;
8. Macroscopic transport models - fundamental model (relation q, k, v) and its use in various situations, including model names, basic mathematical relations, parameters and limits of models and graphical expression; role of occupancy, partial 2D projection of the model, relation to traffic quality, traffic quality levels, relation to road capacity, relation to the number of lanes and directions, examples of applications and use of models;
9. Microscopic traffic models - Lt model, relation to vehicle kinematics, safe distance models, vehicle tracking models, psycho-physical models, collision traffic flow models, model sensitivity, model stability, basic mathematical relationships, model parameters and limits, graphical expression, examples of model applications;
10. Shock waves - definition of waves and descriptive quantities, examples, macro and micro view, types of waves according to the direction of propagation, wave discontinuity, problems of waves in narrow throats, problems of waves at NNW, graphical expression, examples of applications of shock wave models, stop & go;
11. Queue theory - definition of the queue and its role in transport, the process of queue creation and disintegration, macro and micro view, deterministic and stochastic view, input requirements, examples of queue applications on SSZ, standard and extended queue diagram, relation to road capacity, descriptive quantities of queues, quantities describing queue length and queue delays, examples of typical queue patterns;
12. Use of transport models - in the field of traffic management, influencing traffic participants, penalties for offenses, or in the field of other use of ITS, applications for nodes, lines and complex transport area / network, variants for saturated network, principle of expert systems and support of work of traffic dispatcher, input and output quantities of models, goal of application of models, assessment of traffic management quality, types of process management and their suitability for traffic management, relation of models to hierarchical structure of ITS;
13. Traffic excesses - definition, traffic excesses I. and II. type, automatic detection of excesses - principles of sample recognition algorithms and prediction algorithms; importance of excess detection level, false alarms, detection time, California algorithm, MEX algorithm, hydrodynamic analogy, relationship between excesses and queues, shock wave coupling;
14. Data management for transport models - data volume vs. information content, data evaluation process (cleaning, filtering, integration, transformation), typical errors and their reasons, typical methods and their use, classification methods (k-NN method, decision trees), regression models, correlation

D. ITS IN RAILWAY

1. Importance and purpose of railway vehicle safety, basic principles of railway vehicle safety;
2. The principle of operation of train protection devices used in the Czech Republic, the principle of operation of train protection devices used in Western countries;
3. The meaning and purpose of ERTMS / ETCS, legislation and technical specifications related to ERTMS / ETCS;
4. ETCS architecture and interface, application levels;
5. The principle of train location on the infrastructure, configuration and lining of balises;
6. Problems of static profiles and gradients, determination of MRSP;

7. Principle of operation of the ETCS system (static and dynamic running profiles, train running supervision under the braking curve);
8. Operating modes and ETCS modes, principle of transitions between operating modes, procedures in the ETCS system;
9. The issue of issuing driving authorizations (movement authority);
10. Principle of communication in the ETCS system (packets and messages);
11. Architecture of systems and the principle of control and security of railway traffic - historical development;
12. Principles of traffic management with ETCS, application levels 1 and 2 (mixed and exclusive traffic);
13. Principles of traffic management with ETCS application level 3 (requirements and prerequisites for deployment);
14. Architecture and principles of UGTMS system, architecture and principle of CBTC system;
15. Vision of ITS-R Intelligent Transport Systems, Railway 4.0 concept;
16. Principles and requirements for ensuring the reliability and security of ITS-R;
17. Communication technologies in infrastructure (data transmission networks), wireless communication technologies GSM-R, FRMCS;
18. Principle of the ATO system, link to the traffic management system and the ETCS system;
19. Architecture of information systems on the SŽ network, integration of the ETCS system, ATO;

E. INTELLIGENT VEHICLE

1. Systems, description, functions, types of control and response, PID regulator main principal, application, and tuning methods;
2. Vehicle energy consumption model, main forces;
3. Internal combustion engine main principle, Fuel Air mixture, effect on engine efficiency, consumption, and exhaust emissions;
4. Engine control system (ECS) description, functions, subsystem description and main components, sensors and actuators used in ECS, types, functions, and principal;
5. Fuel injection system (FIS) description, function, types, main component, and basic principle, sensors and actuators used in FIS;
6. Ignition system (IS) description, function, types, main component, and basic principle, sensors and actuators used in IS;
7. Anty Lock brake system (ABS), functions, main component, and basic principle, sensors and actuators used in ABS;
8. Electronic Stability Program functions, main component, and basic principle, sensors and actuators used in ESP;
9. Traction Control System (TCS) functions, main component, and basic principle, sensors and actuators used in TCS;
10. Active and passive safety systems, name and describe main systems used in modern vehicles, describe principle of operation, purpose, main components, and algorithms for example SRS (airbags), Load Limiters;
11. Modern system used in vehicles lighting, description, functions, and main components and principle of operation;

12. **Driver comfort and assist system, name and describe main systems used in modern vehicles, describe principle of operation, purpose, main components, and algorithms, for example Cruise Control, Lane assist;**
13. **Multiplexing in car electronic systems, OSI model. CAN protocol description, error management in CAN bus, and network topology;**
14. **Electrical and hybrid vehicles main types and different architecture for Parallel Hybrid vehicles, principle of operation and main components. Advantages of Hybrid technology in comparison to ICE;**
15. **Electrical Machines, types. Torque speed characteristic, motor efficiency, motor as a brake, and types of control for brushed DC motor;**
16. **Voltage convertors and regulators, types, main components, basic electrical diagram, and principle of operation;**
17. **Types of electric batteries used in EV (Electric Vehicle), main battery characteristics, and parameters.**