**“Fundamentals of ITS”**

**Syllabus CT.07/2**

**Dr Jacek Oskarbski**

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Version 1

# Name of the course

**Fundamentals of ITS -** Traffic Sensors Technologies, Data Acquisition and Processing, Communications, ITS Architectures & Services, and Systems Fundamentals

# ECTS credits

6 Credits, (**45 hours of Theory + 30 hours of Exercises & Lab**), 2nd semester

# Objectives

This course familiarizes students with the intelligent techniques and their applications in transportation systems. Within the module students will be introduced to some of the basic concepts of Intelligent Transport Systems in road and railway transportation as well as in supply chain networks. The course will enable students to understand the potential of key technologies (information and communication technologies) in the acquisition, collection, processing and transfer of data for transport process management purposes. Students will be familiarized with different approaches within ITS architectures as well as with the functional structure and the needs of transport process users (ITS services), the logical and physical structure of ITS. Examples of ITS applications in road transport, railway transport and in the supply chain will be presented. Students will be familiarized with tools for planning ITS architecture.

Overall, the lecture provides to students a solid background in the ITS architecture planning. The backgrounds gained by students are further applied in real-world scenarios selected in the road and railway transportation as well as in supply chain networks.

# Learning outcomes

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

* To explain the need for intelligent techniques in transport systems
* To identify the basic design problems of Intelligent Transport Systems
* Mastering the tools/instruments for planning the ITS architecture, taking into account the needs of transport process users and the services that can be provided to them (Tutorials/exercises - ITS architecture creating with the FRAME Architecture tools)
* To familiarise students with the basic principles of using ICT technology and the possibilities of using technology in ITS services.
* To familiarize students with the possibilities and methods of acquisition and processing data from sensors.
* To familiarize students with the structures of databases in Traffic Management Centres/Train Operation Management Centres and for what purpose are used data from sensors on the road and data from connected vehicle positioning and vehicle identification systems.

# Contents

1. **General introduction**
	1. Importance of Intelligent Transportation Systems in road and railway transportation as well as in supply chain networks
	2. Definition of some important keywords and their illustration through concrete examples: *Intelligent Transportation Systems, Traffic Sensors Technologies, Data Acquisition and Processing, ITS Architectures & Services, Information and Communication Technologies, V2V, V2I, V2X*
	3. The historical context of ITS from both public policy and market economic perspectives
	4. Benefits of ITS
2. **Sensors technologies and Data Requirements for ITS**
	1. **Applications of Sensor Data to Traffic Management – examples of strategies, algorithms and requirements**
		1. Traffic signal parameters
		2. Incident detection
		3. Ramp metering
		4. Speed management
		5. Coordinated operation of motorways and alternative roads (including Advanced Traveller Information Systems)
		6. Traffic data collection
		7. Using sensor data to characterize, detect, and analyze sensor failure modes
		8. Detection of priority vehicles
		9. Overheight and Weigh-in-Motion sensors
		10. Weather and surface condition sensors
		11. Vehicle-Mounted Sensors that Enhance Safe Operation
		12. Measures of data uniformity
		13. Statistical Measures of Data
		14. Use of data to supply transport models
	2. **Traffic Flow Sensor Technologies**
		1. Video Image Processor
		2. Microwave Radar
		3. Laser Radar Sensors
		4. Infrared Sensors
		5. Ultrasonic Sensors
		6. Passive Acoustic Array Sensors
		7. Inductive Loop Detectors
		8. Magnetic Sensors
		9. Traffic Flow Data from Automatic Vehicle Identification Transponders
		10. Traffic Flow Data from Mobile Devices
		11. Sensor Combinations
	3. **Sensors in railway transportation**
		1. Signal Sensing Technologies of Traction System Sensors
		2. Sensor Data Acquisition and Processing
		3. Sensor Fault Diagnosis
		4. Intelligent Sensor Technology
3. **Information and Communication Technologies in ITS and system fundamentals**
	1. **Importance of communication and computer technology in the ITS**
	2. **Transponders and Communication systems**
	3. **Information Management, Traffic Management Centers (TMC), Train Operation Management Centres**
	4. **IT networks: transmitters, receivers, transmission media. Data transmission protocols.**
	5. **Local and Wide Area Networks, LAN, WAN. Rules of network connection.**
	6. **Brief overview of wireless systems, e.g. GSM, GSM-R, VSAT, WiFi, GPRS. Wireless sensor networks WSN. Standardization.**
	7. **Elements of Positioning, Vehicle Location and Route Navigation and Guidance concepts**
		1. GPS
		2. Automatic Vehicle Location (AVL)
		3. Automatic Vehicle Identification (AVI)
	8. **Geographic Information Systems fundamentals and applications**
	9. **Data collection, data storage, data bases in ITS, big data**
	10. **Video data collection and analysis**
	11. **Connected Vehicle Technology**
	12. **Data Fusion at the Traffic Management Centres**
		1. Definition of Data Fusion
		2. Processing levels and methods
		3. Data Fusion Architectures
		4. Intelligent systems overview
* Expert systems,
* Bayesian Inference
* Dempster-Shafer Inference
* Voting Fusion
* fuzzy logic systems,
* artificial neural networks,
* evolutionary computations,
* multi-agent systems
1. **ITS Architectures & Services**
	1. **ITS user services and applications**
		1. Travel and traffic management
		2. Public transportation operations
		3. Electronic payment
		4. Commercial Vehicle operations and ITS services in supply chain networks
		5. Advanced vehicle control and safety systems
		6. Emergency management
		7. Information management
		8. Automatic Train Control (ATC)
		9. Rail Traffic Management Systems and Train Control Systems (e.g. ERTMS, ETCS)
		10. Maintenance and construction management
	2. **ITS Architecture**
		1. National ITS architecture
		2. User services and their requirements
		3. Logical architecture
		4. Physical architecture
		5. Market packages
	3. **Railway Intelligent Transportation System architecture**
	4. **ITS Planning**
		1. Planning integrated ITS using ITS Architecture
		2. Transportation planning and ITS
		3. Integrating ITS into Transportation planning

# 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**

* Lawrence A. Klein, Sensor technologies and Data requirements for ITS. Boston : Artech House, ©2001. Artech House ITS library. ISBN: 158053077X 9781580530774
* Thill Jean-Claude, Geographical Information Systems in Transportation Research, Pergamon, 2000.
* J.M. Sussman, Perspectives on Intelligent Transportation Systems (ITS), Springer, 2005
* M.A. Chowdhury and A. Sadek, Fundamentals of Intelligent Transportation Systems Planning, Artech House, 2003
* ITS Hand Book 2000: Recommendations for World Road Association (PIARC) by Kan Paul Chen, John Miles

**Selected relevant Publications**

* Guerrero-Ibáñez J, Zeadally S, Contreras-Castillo J. Sensor Technologies for Intelligent Transportation Systems. Sensors (Basel, Switzerland). 2018;18(4):1212. doi:10.3390/s18041212.
* Feng J, Xu J, Liao W, Liu Y. Review on the Traction System Sensor Technology of a Rail Transit Train. Sensors (Basel). 2017;17(6):1356. Published 2017 Jun 11. doi:10.3390/s17061356
* Li P., Jia L.-M., Nie A.-X. (2003). Study on railway intelligent transportation system architecture IEEE Conference on Intelligent Transportation Systems, Proceedings, ITSC, 2 , art. no. 1252729 , pp. 1478-1481.
* E. Bekiaris and Y.J. Nakanishi, Economic Impacts of Intelligent Transportation Systems: Innovations and Case Studies, Elsevier/JAI, 2004
* F. Van Quickenborne, F. De Greve, F. De Turck, I. Moerman, and P. Demeester, Management of aggregation networks for broadband Internet access in fast moving trains. BERLIN: SPRINGER-VERLAG BERLIN, 2005, pp. 273-283.
* J. G. Andrews, A. Ghosh, and R. Muhamed, Fundamentals of WiMAX: Understanding Broadband Wireless Networking Prentice Hall, 2007.
* Wireless Technologies in Intelligent Transportation Systems (Transportation Issues, Policies and R & D), Ming-Tuo Zhou, Yan Zhang, Laurence T. Yang, Nova Science Publishers, 2010
* http://frame-online.eu/
* https://www.its.dot.gov/research\_archives/arch/architecture\_plan.htm

**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

**\*** FRAME Architecture Planning Tools:

* **Browsing tool and Selection tool**.

http://frame-online.eu/