UNIVERSITÀ DEGLI STUDI DI NAPOLI FEDERICO II

SCUOLA POLITECNICA E DELLE SCIENZE DI BASE

DIPARTIMENTO DI INGEGNERIA CIVILE, EDILE E AMBIENTALE

STUDY GUIDE

Master of Science
TRANSPORTATION ENGINEERING AND MOBILITY

(MSc class in Civil Engineering, LM-23)

THE ACADEMIC YEAR 2021/2022

Napoli, July 2021

Study course goals and employment opportunities

The MSc in Transportation Engineering and Mobility aims to respond to the profound transformations taking place - or expected soon - in the field of transportation. The goal is to train new engineers to meet transformation challenges and satisfy the demand for new skills and competencies in transportation and mobility, coming from the job market at a national and international level.

A complex system of infrastructures, terminals, services and means satisfies the mobility demand of passengers and the request for transport of goods. On the other hand, these demands are evolving at an accelerated pace, thanks to various factors of change that often act in an interconnected manner. For instance, the convergence of cutting-edge technological innovations plays a crucial role in the increasing penetration of digital technologies in automated, connected, and cooperative vehicles, transport infrastructures, last-mile distribution of goods, and others. These changes influence people's mobility behaviour and how people and enterprises consume final and intermediate goods. All the previous can be framed into the big picture of some main socio-economic trends, such as population ageing, migration, and urbanisation. Commuters are changing their style of life and attitudes. They are increasingly oriented towards rational behaviour and inspired by the emerging paradigms of the sharing economy. Commuters are every day more sensitive to social, economic, energetic, and environmental sustainability as well.

The global transport industries start to compete also in the field of sustainability and the modernisation of the sector. They begin to perceive sustainability as to be a significant competitive advantage. Industry and services in transportation and mobility increasingly focus on new fields of activity and business models based on increased connectivity between infrastructure, means of transport, travellers, and goods with a view to door-to-door mobility and seamless transport services offered and marketed. The recent pandemic emergency also modifies the mobility behaviour, likely with permanent effects.

Concerning transport infrastructure networks, on the one hand, extensive European and Euro-Asian network projects are being carried out, and emerging countries are gradually upgrading their transport infrastructure. On the other hand, countries with mature economies suffer from the obsolescence of their infrastructures, built in the 1960s and 1970s. It is now impossible to postpone a vast program of maintenance works. A new need for planning and prioritising interventions to rehabilitate and re-functionalised the network of infrastructures is evident, and the theme of the resilience of transportation infrastructures takes the focus.

Moreover, resources are scarce, while needs and expectations are growing. Relatively new phenomena take the floor in the distribution of freights, mainly stimulated by the fast-growing online purchasing.

Therefore, it is necessary to organise and manage transport and mobility in a more innovative way, interconnecting services, modes, vehicles, and infrastructures and learning to understand and manage complexity, putting at the service of the system new knowledge capable of favouring or creating innovative business models both for the large transport operators and for the complex and distributed ecosystem of mobility services.

The MSc trains a new generation of experts to compete under changed conditions and perspectives by leveraging the acquired skills in modelling and simulation of transportation systems, and thus boosting the economic growth in transportation and, at the same time, ensuring sustainability goals.

To this aim, the MSc in transportation engineering and mobility at the University of Naples Federico II offers a learning approach based on acquiring a wide range of specific skills.

Training activities are integrated with experiential and laboratory teaching, corroborated by other helpful skills for insertion into work. Students explore applicative problems in their internship and thesis and develop and test solutions with industrial stakeholders.

As a result, the master's graduates in Transportation Engineering and Mobility work in highly innovative professional contexts, characterised by a significant propensity to use new technologies. They are qualified experts in the planning, programming, design and operation of infrastructures, terminals, networks, services, and technological and organisational processes (including highly innovative ones) related to the mobility of people and the transport and distribution of goods. The job tasks of the master's graduate in Transportation Engineering and Mobility cover a wide range of activities and include:

- adaptation, maintenance and operation under efficient and safe conditions of adequate, accessible, usable and sustainable infrastructures, plants and services, aimed at satisfying settlement, productive, economic and social functions;
- design, implementation and control of complex networks, consisting of infrastructure, services and organisational and pricing systems to support modern, sustainable, safe, automated and connected mobility behaviour of people and transport and distribution of goods, as well as original and innovative solutions-oriented in this direction;
- analysis, mathematical characterisation, forecasting, control and management of mobility demand, traffic flows and outflows of vehicles, persons and goods
- support and guidance in the processes of digital transformation of transport infrastructures, including the design, implementation and operation of Smart Roads, also achieved through services based on the connection between vehicles and with infrastructures (driving services, traffic information and management of transport networks with cooperative logics);
- development and design of road safety, concerning both infrastructures and active vehicle safety, also implemented through cooperative communication and driving solutions;
- application of circular economy and material re-use paradigms to transportation engineering;
- estimation and assessment of the impacts of infrastructure construction, the introduction of technological innovation in the sector, the sharing of decision-making processes, including through consultation and public involvement;
- design, management and promotion of the services supplied by transport operators in a market of regulated competition and competition for the attraction of customers;
- conception, design, implementation and management of solutions in the field of MaaS (Mobility as a Service), modal integration, soft mobility, shared mobility, as well as sizing of technological, organisational and pricing systems and design/management of business development plans linked to the optimisation of technical resources for the provision of services;
- testing of increasingly automated driving solutions in realistic traffic contexts and assessment of the effects of innovation in terms of flow efficiency and opportunities for mobility and transport;
- design and operation of complex systems for CCAM (Cooperative Connected and Automated Mobility).

The job opportunities of the master's graduate in Transportation Engineering and Mobility are: in public administration agencies responsible for mobility and transportation; in operational units dealing with transport infrastructures, networks and services; in large public and private companies dealing with the production and management of mobility services, transport systems and autonomous and connected vehicle fleets; in small and

medium-sized companies with highly innovative characteristics in the mobility sector. The master's graduate covers job activities with highly specialised professional, intellectual and scientific functions in transport engineering, with technical functions in the early stages of the job career.
More specifically, the knowledge, skills and abilities acquired by the master's graduates in Transportation Engineering and Mobility allow for extensive employment opportunities, ranging over a significant number of sectors. These include the use of vehicles and other industrial products as components of mobility systems; road and railway construction; intercity and urban passenger and freight rail transport; maritime and coastal transport and inland waterway transport of passengers and goods; air transport of passengers and goods; transport support activities, including insurance and management consultancy; technical testing and analysis; research and experimental development in the field of natural sciences and engineering; market research and opinion polls concerning transport and mobility; vehicle rental, including the new growing business of car-sharing and bike-sharing; transport services in support of all enterprises; collective services offered by public administrations.
Employment opportunities include: research and innovation departments in companies in the automotive supply chain, with reference to the development of automated and connected vehicles, integrated in traffic and mobility environments; transport infrastructure construction companies, with reference to digital modelling activities of infrastructures for life cycle management and maintenance; companies and operators for the production, management and operation in the field of intelligent transport systems, autonomous and connected mobility and vehicle fleets; companies, bodies, consortia and agencies for the management and control of transport systems; companies and operators for the management of road, rail, port, airport and intermodal/multimodal terminals and nodes for the transport of passengers and goods; as well as global and local operators of mobility and goods transport and distribution; owners and concessionaires of modal and multimodal transport infrastructures, networks and services at different territorial levels; companies, operators and managers of transport hubs and mobility managers in shopping centres; operational traffic control centres for different modes of transport, as well as for intermodal mobility and production/management of related specialised tools; innovative companies in the field of shared mobility and mobility as a service; companies of car-sharing, bike-sharing and other mobility services for people based on the management of vehicle fleets subjects from the insurance sector, for the design and testing of new business models for liability in the context of autonomous driving, connected driving, mobility behaviour strongly oriented towards sharing and intermodality/multimodality; public and private bodies, companies and operators in the field of testing, validation, certification and homologation in realistic traffic environments for assisted, automated and connected driving systems and for advanced systems for interoperability between vehicles and infrastructures; engineering consulting companies in the automotive sector and more generally in the connected mobility sector; operators and companies in the tourist mobility sector; consulting firms operating in the field of economic, financial and sustainability assessment of investments and projects related to transport infrastructure networks; holding companies and management departments of large railway, motorway, aviation and road companies; public and private entities operating in the field of planning and management of large events involving the movement of people and vehicles and the optimisation of vehicular and pedestrian flows; national, local and supranational control and regulatory authorities; civil protection administrations, bodies, structures and operators, for the purposes of developing, planning and implementing programmes in favour of the resilience of transport infrastructures and networks, as well as emergency management programmes and evacuation plans

Study programs (the Academic Year 2021-22)

The *General* Study Program allows students to compose their program following the appropriate rules. The MSc didactic management board evaluates all submitted programs composed on the General Study Program.

Three *Pre-compiled* Study Programs are available too. The MSc didactic management board automatically approves any of these programs as the submission plays the role of formal communication for the chosen pre-compiled program.

Finally, two specific *Smart Infrastructures Developer* Study Programs ensure compliance with the rules for enrolling on the minor Smart Infrastructures within the national project *Tecnologie per le transizioni*, a joint program with Politecnico di Bari, Politecnico di Milano, Politecnico di Torino and the Universities of Bologna, Padova, Palermo and Roma La Sapienza, with the support by the Ministry of the University and Research.

General Study Program

Course	ETCS	Scientific Field Code	Type (*)	Skill Area	Pre-requirements
First Year – first term					
Language Skills	**3**		**6**	**Other skills**	**None**
Positioning and location-based services	**9**	**ICAR/06**	**2**	**Civil Engineering**	**None**
A course from table III	*9*		*4*	*Measures, analyses, decision support*	
A course from table IV	*9*		*4*	*Enabling ICT and industrial technologies*	
First Year – second term					
Machine Learning and big data	**9**	**ING-INF/05**	**4**	**Enabling ICT and industrial technologies**	**None**
Intelligent Transportation Systems	**9**	**ICAR/05**	**2**	**Civil Engineering**	**None**
Road Safety	**9**	**ICAR/04**	**2**	**Civil Engineering**	**None**
Autonomous Choice (see table V for suggestions)	*A = 6/9*		*3*	*Autonomous choice*	
Second Year – first term					
A course from Table I or II	*9*		*2*	*Civil Engineering*	
A course from table IV	*9*		*4*	*Enabling ICT and industrial technologies*	
Second Year – second term					
A course from Table I or II	*9*		*2*	*Civil Engineering*	
Autonomous Choice	15 - A		3	Autonomous	

(see table V for suggestions)				choice	
Lab / Internship	**9**		**6**	**Other skills**	
MSC Thesis	**12**		**5**	**Ing. Elettrica**	

(*) Types of learning activities (Decree)

Learning Activity	**1**	**2**	**3**	**4**	**5**	**6**	**7**
Reference Decree 270/04	Art. 10 parag. 1, a)	Art. 10 parag. 1, b)	Art. 10 parag. 5, a)	Art. 10 parag. 5, b)	Art. 10 parag. 5, c)	Art. 10 parag. 5, d)	Art. 10 comma 5, e)

Table I + II: Transportation Engineering, roads and railways

Course	ETCS	Scientific Field Code	Type (*)	Pre-requirements
First-term				
Testing and validation of automated road vehicles	9	ICAR/05	2	
Traffic control	9	ICAR/05	2	Basic background on transportation modeling (ICAR/05)
Transport planning and appraisal	9	ICAR/05	2	Basic background on transportation modeling (ICAR/05)
Second term				
Freight and logistics	9	ICAR/05	2	Basic background on transportation modeling (ICAR/05)
Railway and transit services	9	ICAR/05	2	Basic background on transportation modeling (ICAR/05)
Sustainable Road Materials	9	ICAR/04	2	

Table III: Measures, analyses, decision support

Course	ETCS	Scientific Field Code	Type (*)	Pre-requirements
First-term				
Digital maps and geological 3D Models	9	GEO/05	4	
Statistical lab for industrial data analysis	9	SECS-S/02	4	
Structural health monitoring for infrastructures	9	ICAR/09	4	Basic background on structural engineering (ICAR/09)
Second term				
Tunnels and Underground Structures	9	ICAR/07	4	Basic background on geotechniques (ICAR/07)
Instrumentation and Measurements for Smart Industry	9	ING-INF/07	4	

Table IV: Enabling ICT and industrial technologies

Course	ETCS	Scientific Field Code	Type (*)	Pre-requirements
First-term				
Electric systems in transportation	9	ING-IND/32	4	
Energy management for transportation	9	ING-IND/33	4	
Systems and Control fundamentals	9	ING-INF/07	4	
Second term				
Image processing for computer vision	9	ING-INF/03	4	

Real-time systems	9	ING-INF/05	4	

Table VI: Suggested alternatives for autonomous choices

Course	ETCS	Scientific Field Code	Type (*)	Pre-requirements
First-term				
Operational Research	9	MAT/09	3	
Mathematical Physical Models	9	MAT/07	3	
All courses of the first period from Tables I to V	*9*		*3*	
Second term				
Resilience of Transportation Systems	6	ICAR/05	3	
Smart Roads and cooperative driving	6	ICAR/05	3	
Resilience of geotechnical systems	6	ICAR/07	3	
Lab for road safety	6	ICAR/04	3	
Fondamenti di diritto per l'ingegnere	9	IUS/01	3	
Project Management per le opere civil	9	ING-IND/35	3	
Meccanica del Veicolo	9	ING-IND/13	3	
All courses of the first period from Tables I to V	*9*		*3*	

Pre-compiled Study Programs

(internships for pre-compiled study programs are pre-defined together with relevant stakeholders)

Smart Mobility Study Program

Course	ETCS	Scientific Field Code	Pre-requirements
First Year, first-term			
Language Skills	**3**		**None**
Positioning and location-based services	**9**	**ICAR/06**	**None**
Statistical Lab for Industrial data analysis	**9**	**SECS-S/02**	**None**
Systems and Control fundamentals	**9**	**ING-INF/07**	**None**
First Year, second-term			
Machine Learning and big data	**9**	**ING-INF/05**	**None**
Intelligent transportation Systems	**9**	**ICAR/05**	**None**
Road Safety	**9**	**ICAR/04**	**None**
Real-time systems	**9**	**ING-INF/05**	**None**
Second Year, the first-term			
Testing and validation of automated road vehicles	**9**	**ING-INF/05**	**None**
Energy management for transportation	**9**	**ING-INF/32**	**None**
Second Year, second-term			
Railway and transit services	**9**	**ICAR/05**	Basic background on transportation modeling (ICAR/05)
Smart Roads and cooperative Systems	**6**	**ICAR/05**	**None**
Lab / Internship	**9**		
MSC Thesis	**12**		

Smart Planning Study Program

Course	ETCS	Scientific Field Code	Pre-requirements
First Year, first-term			
Language Skills	3		None
Positioning and location-based services	9	ICAR/06	None
Digital maps and geological 3D models	9	GEO/05	None
Systems and Control fundamentals	9	ING-INF/07	None
First Year, second-term			
Machine Learning and big data	9	ING-INF/05	None
Intelligent transportation Systems	9	ICAR/05	None
Road Safety	9	ICAR/04	None
Railway and transit services	9	ING-INF/05	None
Second Year, first-term			
Traffic control	9	ING-INF/05	None
Energy management for transportation	9	ING-INF/32	None
Second Year, second-term			
Freight and logistics	9	ICAR/05	Basic background on transportation modeling (ICAR/05)
Smart Roads and cooperative Systems	6	ICAR/05	None
Lab / Internship	9		
MSC Thesis	12		

Resilient networks Study Program

Course	ETCS	Scientific Field Code	Pre-requirements
First Year, first-term			
Language Skills	3		None
Positioning and location-based services	9	ICAR/06	None
Digital maps and geological 3D models	9	GEO/05	None
Electric Systems in Transportation	9	ING-IND/32	None
First Year, second-term			
Machine Learning and big data	9	ING-INF/05	None
Intelligent transportation Systems	9	ICAR/05	None
Road Safety	9	ICAR/04	None
Tunnels and underground structures	9	ICAR/07	None
Second Year, first-term			
Transport planning and appraisal	9	ING-INF/05	None
Energy management for transportation	9	ING-INF/32	None
Second Year, second-term			
Sustainable road materials	9	ICAR/04	Basic background on transportation modeling (ICAR/05)
Resilience of transportation systems	6	ICAR/05	None
Lab / Internship	9		
MSC Thesis	12		

Smart Infrastructures Developer Study Programs

Within the MSc in Transportation Engineering and Mobility, it is possible to get the diploma in *Smart Infrastructure Developer* too. Activities for additional 10 ETCS are required and include in the study program appropriate courses. The general rules for the Smart Infrastructures Developer diploma are available at http://www.scuolapsb.unina.it/index.php/homea/9-in-evidenza-highlights/856-ingegneria-al-via-i-minor-in-green-technologies-e-in-smart-infrastructures
Two specific study programs (SID_A and SID_B) ensure compliance with the general rules. The programs include 10 ETCS activities additional to the MSc.

Smart Infrastructure Developer – study program (SID_A)

Course	ETCS	Scientific Field Code	Pre-requirements
First Year, first-term			
Language Skills	3		None
Positioning and location-based services	9	ICAR/06	None
Statistical lab for industrial data analysis	9	SECS-S/02	None
Systems and Control fundamentals (+)	9	ING-INF/07	None
First Year, second-term			
Machine Learning and big data (+)	9	ING-INF/05	None
Intelligent Transportation Systems	9	ICAR/05	None
Road Safety	9	ICAR/04	None
Resilience of Geotechnical Systems	6	ICAR/07	None
Second Year, first-term			
Transport Planning and Appraisal	9	ICAR/05	Basic background on transportation modeling (ICAR/05)
Energy management for transportation	9	ING-INF/32	None
Digital maps and geological 3D Models	9	GEO/05	
Second Year, second-term			
Infrastructure-Building Information Modeling (I-BIM)	9	ICAR/04	
Lab / Internship	7		None
Smart Infrastructures Lab (+)	2		None
MSC Thesis	12		None
Additional activities for the Smart Infrastructure Developer diploma			
Course	**ETCS**	**Scientific Filed Code**	**Pre-requirements**
First or second Year, second-term			
Resilience of Transportation Systems (+)	6	ICAR/05	None
Workshops, labs and seminars (+)	4		None

(+) These activities sum up to 30 ETCS, 20 within the MSc TEAM and 10 as additional activities. They allow for the recognising of the Smart infrastructure Developer diploma supplement

Smart Infrastructure Developer – study program (SID_B)

Course	ETCS	Scientific Field Code	Pre-requirements
First Year, first-term			
Language Skills	3		None
Positioning and location-based services	9	ICAR/06	None
Statistical lab for industrial data analysis	9	SECS-S/02	None
Systems and Control fundamentals (+)	9	ING-INF/07	None
First Year, second-term			
Machine Learning and big data (+)	9	ING-INF/05	None
Intelligent Transportation Systems	9	ICAR/05	None
Road Safety	9	ICAR/04	None
Smart Roads and Cooperative Systems	9	ING-INF/05	None
Second Year, first-term			
Transport Planning and Appraisal	9	ICAR/05	Basic background on transportation modeling (ICAR/05)
Energy management for transportation	9	ING-INF/32	None
Traffic Control	9	ICAR/05	Basic background on transportation modeling (ICAR/05)
Second Year, second-term			
Railway and transit services	9	ICAR/05	Basic background on transportation modeling (ICAR/05)
Lab / Internship	7		None
Smart Infrastructures Lab (+)	2		None
MSC Thesis	12		None
Additional activities for the Smart Infrastructure Developer diploma			
Course	**ETCS**	**Scientific Filed Code**	**Pre-requirements**
First or second Year, second-term			
Resilience of Transportation Systems (+)	6	ICAR/05	None
Workshops, labs and seminars (+)	4		None

(+) These activities sum up to 30 ETCS, 20 within the MSc TEAM and 10 as additional activities. They allow for the recognising of the Smart infrastructure Developer diploma supplement

Calendar of teaching activities and exam periods (the academic year 2021/2022

For the calendar, go to the website of the Scuola Politecnica e delle Scienze di Base:
http://www.scuolapsb.unina.it/downloads/materiale/didattica/ingegneria/ING_didattica_2021_2022.pdf

MSc TEAMS	1st teaching term	1st exam terms	March Exam term	2nd teaching term	2nd exam term	3rd exam term	October exam term
I and II Year	20/09/2021 17/12/2021	18/12/2021 26/02/2022	02/03/2022 31/03/2022	07/03/2022 10/06/2022	11/06/2022 30/07/2022	01/09/2022 30/09/2022	01/10/2022 31/10/2022

1st teaching term vacations San Gennaro: 19 September (Sunday); All Saints' Day: 1 November (Monday); Immacolata: 8 December (Wednesday); Christmas: from 24 December (Friday) to 6 January (Thursday).

Carnival Holidays Monday 28 February and Tuesday 1 March

2nd teaching term vacations Easter: from Thursday 14 April to Wednesday 20 April; Liberation Day: 25 April (Monday); Labour Day: 1 May (Sunday); Republic Day: 2 June (Thursday)

All dates are in the day/month/year format

Scheduling of Exams Sessions

For the scheduling of the exam sessions, go to the website of the Scuola Politecnica e delle Scienze di Base:
http://www.scuolapsb.unina.it/downloads/materiale/esami/LM-TEAM_esami.pdf

Contacts

Chair of the MSc: Prof. Gennaro Nicola BIFULCO – Dipartimento di Ingegneria Civile, Edile e Ambientale - phone 081/7683883 - e-mail: gnbifulc@unina.it

Contact person for the ERASMUS program: Prof.ssa Francesca Pagliara – Dipartimento di Ingegneria Civile, Edile e Ambientale - e-mail: francesca.pagliara@unina.it

Further contact persons at the websites (also useful for info, news and resources):
https://www.transportengineering.it/eng
https://www.dicea.unina.it/?page_id=3232

Courses fact sheets

DIGITAL MAPS AND GEOLOGICAL 3D MODELS

SSD	CFU	Year (I or II)			Semester (I or II)		Language	
		I	II		I	II	Italian	English
GEO/05	9	X			X			X

Required/expected prior knowledge: none

Class(es)				
Teacher(s)				

COURSE OBJECTIVES

The course provides general knowledge about engineering geology and its digital application. It is a multidisciplinary subject of study at the intersection of Earth Sciences and Engineering focused on the geologic phenomena and the role of geological variables and environmental conditions in engineering design and construction. Topics include rock and mineral types, soil properties, rock mechanics, geologic structures, active tectonics, geological mapping and earthquake hazards, slope stability and landslides, groundwater, rivers, and flood hazards. The course introduces the general concepts of geological data acquisition through survey techniques and point clouds. The course also provides the basics for managing and elaborating geospatial data with Geographic Information Systems (GIS) and building 3D subsurface geological models.

TABLE OF CONTENTS

- Basic concepts on Geology
  - Earth internal structures and plate Tectonics
  - Identification of rocks and soils
  - Regional geology and the southern Apennines
- Geological mapping
  - Reading and interpretation of topographic maps
  - Digital topographic profiles
  - Reading and interpretation of geologic maps
  - Digital geologic cross-sections
  - Introduction to geodata and GIS
- Investigations for rocks and soils characterization
  - Introduction to the main investigations
  - Reading and interpretation of boreholes
  - Collection and storage of groundwater data using GIS
  - Elaboration of groundwater levels and hydrogeochemical maps using GIS
- 3D Geological modelling
  - Main survey techniques and point clouds management
  - Reconstruction of 3D subsurface geology aimed at hydrogeology models
  - 3D rock masses reconstruction
- Hazard assessments
  - Engineering geology in the seismic risk assessment
  - Landslides and floods
  - Landslides and susceptibility mapping using GIS
  - Groundwater vulnerability methods using GIS and 3D models

EDUCATION METHOD

Lectures, interactive tutorials, laboratory activities and exercises. Field trip aimed at data acquiring.
The used software is prevalently open source and only marginally covered by educational licenses.

TEXTBOOKS AND LEARNING AIDS

Dearman W.R. (1991). Engineering Geological mapping. Butterworth – Heinemann Ltd.
Ferrer M. and I. González de Vallejo (2011). Geological Engineering. CRC Press;
Fetter C.W., Boving T., Kreamer D. (2018). Contaminant Hydrogeology. Waveland press inc.
Freeze A. and Cherry J. (1979). Groundwater. Prentice hall inc.
Griffiths J.S. (2002). Mapping in Engineering Geology. The Geological Society London

Reddy D.V. (2010). Engineering Geology. Vikas Publishing House;
Scientific papers
Notes from the lessons

ASSESSMENT

Assessment is	**Written and Oral**	**X**	**Written Only**		**Oral only**		
In case of written assessment, questions are	**Multiple-choice tests**		**Open questions**	**X**	**Numerical exercises**	**X**	
Other (es: project development, computer test ...)	**Project development and computer test**						

ELECTRIC SYSTEMS FOR TRANSPORTATION

SSD	CFU	Year (I or II)		Semester (I or II)		Language	
		I	II	I	II	Italian	English
IND-IND/33	9	X		X			X

Required/expected prior knowledge: none

Class(es)				
Teacher(s)				

COURSE OBJECTIVES

The course aims to provide general knowledge about power systems for transport applications. There are focused systems for urban and extra-urban mobility. The power infrastructures are studied in terms of components, apparatuses, devices, and systems, widely interconnected. Desing criteria and operating conditions are discussed. Methods and algorithms for simulating power systems for transportation in terms of electrical power flow exchanges are studied. Different design solutions and scenarios concerning energy efficiency and environmental sustainability are examined. The lectures deal with special regards the applications of both Plug-in Electrical Vehicles (PEV) and railway traction systems.

TABLE OF CONTENTS

- The Energy Context of Mobility for urban and extra-urban application
- Operators and Authority of the Market
- Electrical Energy Carriers: advantages and drawbacks for power requirements
- Main Components and Schemes typically used in Power Infrastructures for mobility
- The context of Plug-in Electrical Vehicles (PEV)
- The context of Railway Traction Systems

EDUCATION METHOD

Lectures, numerical exercises, laboratory activities

TEXTBOOKS AND LEARNING AIDS

Notes from the lectures, slides, technical papers. Main textbooks:

- Technologies and Applications for Smart Charging of Electric and Plug-in Hybrid Vehicles, O. Veneri, Springer
- Electromagnetic Compatibility in Railways – A. Ogunsola, A. Mariscotti – Springer
- Electrical Railway Transportation Systems – M. Brenna, F. Foiadelli, D. Zaninelli - Wiley

ASSESSMENT

Assessment is	Written and Oral		Written Only		Oral only	X

In case of written assessment, questions are	Multiple-choice tests		Open questions		Numerical exercises	
Other (es: project development, computer test ...)	**Project development**					

ENERGY MANAGEMENT FOR TRANSPORTATION

SSD	CFU	Year (I, II or III)			Semester (I or II)		Language	
		I	II		I	II	Italian	English
ING-IND/32	9		X		X			X

Required/expected prior knowledge: none

Class(es)				
Teacher(s)				

COURSE OBJECTIVES

In addition to the synthetic knowledge of the main constituents of the electric/hybrid propulsion systems of road and rail vehicles, the course aims to provide analysis methodologies of power trains with particular regard to energy and environmental sustainability aspects. The critical discussion of energy management strategies and algorithms is associated with normative references and significant application examples.

TABLE OF CONTENTS

Classification of propulsion systems. Vehicle dynamics. Vehicle energetics.

Electric road vehicles: power circuits, control systems, on-board equipment. Classification of hybrid configuration (series, parallel, power-split). Principle of operation and design criteria for a passenger car power-split e-CVT transmission.

Classification of energy storage systems for automotive application related to vehicle type (BEV, HEV, PHEV).
Ion lithium batteries. Technology and model. Battery pack and battery management system (BMS).
Other energy storage systems with high power density: supercapacitors and flywheel; KERS.

The powertrain for road vehicles: architectures, main subsystems and performance.
Energy management on-board.
Sizing of an electric vehicle. Sizing of a hybrid vehicle.

Charging systems for electric vehicles. Electric vehicle charging infrastructures and their integration into the electricity grid.

Electric railway propulsion: power circuits, control systems, on-board equipment.
The powertrain for different types of electric traction rail vehicles (heavy-rail passenger train, light rail, urban rail transit). Integration of electric energy storage systems. Energy management considering the interaction between storage equipment on board the train and on the ground.

Application of electric drives outside of the powertrain: HVAC, power steering, battery cooling.

Review of technology for power converters concerning power and voltage range.

Basics of the Life-Cycle Assessment of electric vehicles in comparison with internal combustion vehicles.

Expectations and role played by electric mobility in reducing polluting emissions and increasing the efficiency of road vehicles.

Standards for functional safety of an electric powertrain, concerning Automotive Safety Integrity Level (SIL), IEC 61511.

Standards for AC and DC conductive charging of electric vehicles (EN 61851).

EDUCATION METHOD

Lectures, interactive tutorials, laboratory activities and exercises

TEXTBOOKS AND LEARNING AIDS

Slides, lecture notes, textbooks.

ASSESSMENT

Assessment is	Written and Oral		Written Only		Oral only	X

In case of written assessment, questions are	Multiple-choice tests		Open questions		Numerical exercises	
Other (es: project development, computer test ...)	**Project development**					

FREIGHT AND LOGISTICS

SSD	CFU	Year (I or II)			Semester (I or II)		Language	
		I	II		I	II	Italian	English
ICAR/05	9		X			X		X

Required/expected prior knowledge: basic principles of transport modelling

Class(es)				
Teacher(s)				

COURSE OBJECTIVES

The course aims to illustrate key characteristics of freight and logistics systems and provide students with essential planning, management, and operational capabilities. A twofold perspective covers the topics: on the one hand, looking at private companies supplying freight services; on the other hand, focusing on public bodies in charge of planning, governance, and market regulation.

TABLE OF CONTENTS

Course lectures focus on five key topics:
1. Knowledge of relevant factors and key dynamics of logistics needs from companies' and end-users perspectives, analysis of the interactions between logistics and transport/movement of goods, detailed analysis of the market of freight and logistics, both from the supply and demand sides, at national and international levels.
2. Knowledge of infrastructural assets (vehicles, infrastructures, terminals, technologies, …) and immaterial assets (regulations, costs, fares, acts, ...) of freight transport supply for each transport mode (road, rail, sea, air, inland waterways), with a specific focus on multimodal/intermodal transport and on the analysis of freight terminals (ports, dry ports, logistics platforms, …).
3. Analysis of freight transport demand (characteristics, evolution, data sources) at urban, regional, national, international scales.
4. Mathematical models and quantitative methods for freight system analysis, design and appraisal, with applications to different geographical scales (urban, regional, national, international) and prevailing applications to public planning and policymaking of freight systems.
5. Applications and case studies. Upon being attendants below a maximal threshold, class exercises are using GIS and database software. Visits to Italian ports and logistics platforms are organized as well.

EDUCATION METHOD

Lectures, interactive tutorials, laboratory activities and exercises

TEXTBOOKS AND LEARNING AIDS

Slides, lecture notes, technical papers. Textbooks:
Freight Transport Modelling (2013). Ben-Akiva M., Van der Voorde E., Meersman H. eds. Emerald publishing.
Stopford M. (2008). Maritime Economics (3rd edition). Routledge.
Cascetta E. (2009). Transportation Systems Analysis: Models and Applications. Springer.

ASSESSMENT

Assessment is	Written and Oral	X	Written Only		Oral only	

In case of written assessment, questions are	Multiple-choice tests	X	Open questions		Numerical exercises	X
Other (es: project development, computer test ...)	**Computer test**					

IMAGE PROCESSING FOR COMPUTER VISION

SSD	CFU	Year (I or II)			Semester (I or II)		Language	
		I	II		I	II	Italian	English
ING-INF/03	9		X			X		X

Required/expected prior knowledge: Fundamentals of signal theory

Class(es)				
Teacher(s)				

COURSE OBJECTIVES

Computer vision deals with extracting information from images and videos using computers. It finds application in several domains, including transportation, automotive, security and logistics.
This course aims to enable the student to: i) formalize and model vision problems in both theoretical and practical terms; ii) implement standard vision algorithms focusing on signal processing aspects.

TABLE OF CONTENTS

At the heart of computer vision are image and video processing techniques that combine image and video processing with optimization techniques, training, optics, photometry.
The course introduces computer vision, including image formation, camera geometry, feature detection, description and matching, stereo vision, motion estimation and tracking, segmentation, scene classification and understanding. The course also includes a specific focus on deep learning methods applied to vision problems. Laboratory work (more than 30% of the course) allows students to develop (MatLab) solutions to vision problems both with a classical model-based approach and using data-driven techniques (deep learning). Specific projects are assigned to groups of students To complete the training. Projects are developed during the course (workshops and homework) and presented at the end in a dedicated session.

- Image Formation: introduction, light and colour; geometry of image formation; lab of basic image processing.
- Image proc. Basics: spatial and frequency image filtering; templates, pyramids and textures; lab for image filtering and pyramids
- Detection: edge detection and segmentation watershed; keypoints, corners and DoG; lab for edge detection and segmentation
- Local descriptors and matching: SIFT and matching; lab for key-points and features
- Deep Learning: recall on Machine Learning basics; lab for ConvNets
- Model fitting: geometric transformation; fitting and alignment; Hough transform; Ransac; ICP; object recognition
- Geometry: finite projective camera model and calibration; multiView intro, epipolar geometry; lab for fundamental matrix estimation with RANSAC; stereo Matching and structure from motion
- Project developing, testing and presentation

EDUCATION METHOD

Lectures, laboratory activities and exercises

TEXTBOOKS AND LEARNING AIDS

Slides, lecture notes, technical papers, online short courses and user manuals of software

ASSESSMENT

Assessment is	**Written and Oral**		**Written Only**		**Oral only**	**X**	
In case of written assessment, questions are	**Multiple-choice tests**		**Open questions**		**Numerical exercises**		
Other	Presentation and discussion of homework and lab activities						

INTELLIGENT TRANSPORT SYSTEMS

SSD	CFU	Year (I or II)			Semester (I or II)		Language	
		I	II		I	II	Italian	English
ICAR/05	9	X				X		X

Required/expected prior knowledge: NONE

Class(es)				
Teacher(s)				

COURSE OBJECTIVES

The course provides students with theoretical and technical skills concerning emerging technologies applied to monitoring, management and control of transportation systems

TABLE OF CONTENTS

- Preliminary recall of key concepts of transportation systems engineering
- Transportation systems monitoring techniques
- Introduction to Intelligent Transport Systems (ITS)
- Connected Vehicle technologies (V2V, V2I). Advanced Driving Assistance Systems (ADAS) and Cooperative Connected and Automated Mobility (CCAM)
- Travel Demand Management
- Advanced Traveller Information Systems
- Key concepts of public transport modelling
- Fundamentals for Advanced Traffic Management Systems
    - Urban traffic control
    - Motorway traffic control
- Mobility as a Service
- Shared Mobility

EDUCATION METHOD

Lectures, interactive tutorials, laboratory activities and case studies, project development, learning-by-doing and challenge-based learning

TEXTBOOKS AND LEARNING AIDS

Slides, lecture notes, technical papers.

ASSESSMENT

Assessment is	Written and Oral		Written Only		Oral only	X

In case of written assessment, questions are	Multiple-choice tests		Open questions		Numerical exercises	
Other (es: project development, computer test ...)	Discussion of lab activities and developed projects					

LABORATORY OF ROAD SAFETY

SSD	CFU	Year (I or II)			Semester (I or II)		Language	
		I	II		I	II	Italian	English
ICAR04	6		X			X		X

Required/expected prior knowledge: none

Class(es)				
Teacher(s)				

COURSE OBJECTIVES

The course provides students with theoretical and practical knowledge to assess road safety by innovative methods and tools. Virtual safety analysis receives particular emphasis for both road infrastructures and automated/autonomous vehicles.

TABLE OF CONTENTS

- Introduction to Road Safety
  - Fundamentals
  - Road crashes: definitions, classification, statistics
  - Surrogate measures of safety
  - Human factors for road systems
  - Safety impacts of driver assistance systems and cooperative driving systems
- Introduction to Road Infrastructure Safety Management
  - Road network screening
  - Diagnosis and selection of countermeasures
  - Road safety inspection
  - Road safety audit
- Advanced Virtual Road Safety Analysis
  - Concepts, advantages, classifications, and applications
  - Design of driving simulator experiments
  - Data analysis
- Lab Activities
  - Safety analysis of road infrastructures in a driving simulation environment: 3D roads modelling, scenario authoring, testing with a driving simulator, data collection and analysis.
  - Analysis of road safety impacts of an automated/autonomous vehicle (AV) using a driving simulator: model and implement in the simulation of the AV, worst-case scenarios definition and reproduction, testing with a driving simulator, data collection and analysis.

EDUCATION METHOD

Frontal lectures, in-class exercises, workshops, lab activities.

TEXTBOOKS AND LEARNING AIDS

Slides, lecture notes, technical papers. Textbooks:
AASHTO (2010). Highway Safety Manual, First Edition.
Lord D., Washington S., Montella A. et al. (2018). Safe Mobility: Challenges, Methodology and Solutions. Emeralds.
Hichem A., Lamri N. (2013). Driving Simulation. Wiley-ISTE.

ASSESSMENT

Assessment is	**Written and Oral**		**Written Only**		**Oral only**	X	
In case of written assessment, questions are	**Multiple-choice tests**		**Open questions**		**Numerical exercises**		
Other (es: project development, computer test ...)	Workshop projects presentation						

MACHINE LEARNING AND BIG DATA

SSD	CFU	Year (I or II)			Semester (I or II)		Language	
		I	II	III	I	II	Italian	English
ING-INF/05	9	X				X		X

Required/expected prior knowledge: NONE

Class(es)				
Teacher(s)				

COURSE OBJECTIVES

The course aims to present the main machine learning techniques, covering all aspects from data preparation to performance evaluation, through practical exercises with commercial and/or open-source tools. An introduction to Big Data and Data Analytics lifecycle is also provided, concerning the design of large and complex databases and the process of modelling, acquiring, sharing, analyzing, and visualizing the information embedded into Big Data.

TABLE OF CONTENTS

Data Mining and Machine Learning. Knowledge representation: Trees, Rules, Clusters.
Basic Machine Learning methods: Statistical Modeling, Linear Models, Instance-based learning, Clustering.
Performance Evaluation: Cross-Validation, Cost-sensitive classification, ROC curves.
Advanced Machine Learning: Decision Trees, Support Vector Machines, MLP, Bayesian Network, Hierarchical Clustering, EM, Semisupervised Learning.
Data transformation: attribute selection, PCA, Sampling, Cleansing.
Deep Learning: training and performance evaluation of Deep Networks, Convolutional Neural Networks. Introduction to database systems. Definition of a Big Data system. Data model for Big Data. The Hadoop ecosystem. Yarn. Pig. Hive. Giraph. Spark. NoSQL database: Key-value - Column-family, Graph database systems.
Introduction to Big Data Analytics (BDA): BDA Lifecycle: knowledge discovery in the database, data preparation, model planning, model building, data visualization.
Examples of commercial and open-source Tools: Oracle, IBM Business Analytics, Microsoft Power BI, Microsoft Azure. AWS. SAP Hana

EDUCATION METHOD

Lectures and laboratory activities

TEXTBOOKS AND LEARNING AIDS

Data mining: practical machine learning tools and techniques.— 4th ed. / Ian H. Witten, Frank Eibe, Mark A. Hall, Christopher J. Pal —The Morgan Kaufmann, 2017.
Mining of Massive Datasets", J. Leskovec, A. Rajaraman, J.D.Ullman, 2014 (online book)

ASSESSMENT

Assessment is	**Written and Oral**		**Written Only**		**Oral only**	**X**	
In case of written assessment, questions are	**Multiple-choice tests**		**Open questions**		**Numerical exercises**		
Other (es: project development, computer test ...)	Project development						

MATHEMATICAL PHYSICS MODELS

SSD	CFU	Year (I or II)			Semester (I or II)		Language	
		I	II		I	II	Italian	English
MAT/07	9	X	X		X			X

Required/expected prior knowledge: Calculus, Elementary Mechanics

Class(es)				
Teacher(s)				

COURSE OBJECTIVES

The course is an introduction to mathematical modelling of physical processes. The course presents the Lagrange model of Mechanics, Tensor Calculus, and elements of Continuum Mechanics.

TABLE OF CONTENTS

Vector Spaces. Affine Euclidean Point Spaces. Degree of freedom. Generalized coordinates. Virtual work. D'Alembert principle. Lagrange Equations for a holonomic system. First integrals. Ignorable coordinates. Hamilton's canonical equations. Calculus of variations. The brachistochrone and isoperimetric problem. Integral functionals and extrema. Euler-Lagrange equations. Variational problems with constraints. Hamilton's principle. Legendre transformations. Hamilton's canonical equations. The phase spaces. Canonical transformations. Generating functions. Hamilton-Jacobi Theory. Hamilton- Jacobi equation. Method of separation of variables. Stability of holonomic systems. Liapunov direct method. Liapunov stability and instability theorems. Krasowsky and LaSalle theorems. Linear stability. First approximation method. Routh-Hurwitz criterion

EDUCATION METHOD

Lectures and exercises

TEXTBOOKS AND LEARNING AIDS

ASSESSMENT

Assessment is	Written and Oral		Written Only		Oral only	X

In case of written assessment, questions are	Multiple-choice tests		Open questions		Numerical exercises	
Other (es: project development, computer test ...)						

MEASUREMENT SENSORS AND TRANSDUCERS

SSD	CFU	Year (I or II)			Semester (I or II)		Language	
		I	II		I	II	Italian	English
ING-INF/7	9	X			X			X

Required/expected prior knowledge: none

Class(es)				
Teacher(s)				

COURSE OBJECTIVES

The course provides general knowledge about measurement systems and sensors and their metrological characteristics, both static and dynamic, to point out the main specifications needed to define the best solution according to the required target. The knowledge is complemented by presenting embedded solutions mandated to acquire, process, transmit and visualize measurement data of interest. This way, it is possible for the students to accomplish the main objective of the course, i.e. the definition, implementation and metrological characterization of integrated measurement systems for transportation applications.

TABLE OF CONTENTS

- General principles
  - General measurement system
  - Static characteristics of measurement system elements
  - Accuracy of measurement systems in the steady-state
  - Dynamic characteristics of measurement systems elements
- Measurement uncertainty estimation according to GUM
  - Fundamentals of statistics and probability
  - A-type and B-type estimation of uncertainty in direct measurements
  - Measurement uncertainty estimation in indirect measurements according to JCGM 100:2008
  - Propagation of distributions using a Monte Carlo method according to JCGM 101:2008
- Basic models and operating principles of main sensors
  - Temperature sensors
  - Pressure sensors
  - Accelerometers
  - Linear and angular encoders
  - MEMS technology for measurement sensors
- Implementation on embedded systems
  - Overview on embedded systems
  - Overview on main microcontrollers architectures
  - ARM-based microcontrollers programming
    - General input/output ports;
    - Timers;
    - Analog to digital converters
    - Digital to analog converters
    - Short-range communication protocols
      - Universal Synchronous-Asynchronous Receiver/Transmitter
      - Inter-Integrated Circuit
      - Serial Peripheral Interface
    - Direct memory access;
  - Data acquisition from external sensors
    - Sensors daughter boards
    - MEMS inertial measurement unit
    - Global navigation satellite system
  - Measurement uncertainty estimation
    - A-type and B-type estimation of uncertainty of raw data
    - Measurement uncertainty estimation of filter outputs
  - IoT communication protocols and platform
    - Long Range Wide Area Network (LoRaWAN)
    - Message Queue Telemetry Transport (MQTT)

- Nodered
- Dashboards

- Application examples
  - Fleet management
  - Traffic control
  - Condition monitoring of vehicles and infrastructures

EDUCATION METHOD

Lectures, interactive tutorials, laboratory activities and exercises

TEXTBOOKS AND LEARNING AIDS

Slides, lecture notes, technical papers. Textbooks:
John P. Bentley, Principles of Measurement Systems, Pearson Education Limited, Edinburgh, 2005
S.C. Mukhopadhyay, K. P. Jayasundera, O.A. Postolache - Modern Sensing Technologies, Springer, 2019
Microcontroller, sensors, and GNSS datasheets, user and reference manuals.
Protocols standards and application notes
Platforms API

ASSESSMENT

Assessment is	**Written and Oral**	**X**	**Written Only**		**Oral only**		
In case of written assessment, questions are	**Multiple-choice tests**		**Open questions**		**Numerical exercises**		
Other (es: project development, computer test ...)	Project development and computer test						

OPERATIONAL RESEARCH

SSD	CFU	Year (I or II)			Semester (I or II)		Language	
		I	II		I	II	Italian	English
MAT/09	6		X		X			X

Required/expected prior knowledge: Linear algebra: matrices, vectors, determinants, systems of linear equations. Vector analysis, eigenvalues and eigenvectors, quadratic forms and differential equations. Elements of convex analysis and optimality conditions

Class(es)				
Teacher(s)				

COURSE OBJECTIVES

The main objective of the course is the introduction of the students to the use of mathematical programming models and, in particular, to both linear and nonlinear optimization models (with both continuous and integer variables) and their applications in real-world fields, including control, communications, logistics, services, and industrial production.
As concerns nonlinear programming models, the course aims at providing a comprehensive and rigorous treatment of traditional topics, such as descent algorithms, Lagrange multiplier theory, and duality. In addition, some of the more sophisticated methods are also covered, such as interior-point methods, penalty and barrier methods, least-squares problems, and conditional gradient and subgradient optimization.

TABLE OF CONTENTS

Introduction to Operational Research and Optimization; Linear Programming (LP): Introduction to LP and form of an LP problem; Geometry of continuous LP; The Simplex Method. Integer Linear Programming (ILP): Introduction to ILP; Linear Programming Relaxation; Special ILP problems with unimodular constraints matrix: the Transportation Problem, the Assignment Problem; Solution methods: Exact Methods: Branch & Bound; Cutting Planes, Dynamic Programming; Approximation Methods; Heuristic and Metaheuristic Methods; The 0/1 Knapsack Problem and the Fractional Knapsack Problem.Network flows and graph problems: The Minimum Vertex Cover Problem; The Minimum Spanning Tree Problem; Shortest Path Problems; Project Scheduling Problems: Critical Path Method (CPM); Path Evaluation and Review Technique (PERT); Post-optimization analysis.Nonlinear Optimization: Unconstraint Nonlinear Optimization: Optimality conditions; Gradient Methods: Convergence, Descent Directions and Stepsize Rules; Newton's Method and Variations; Least Squares Problems: the Gauss-Newton Method, Incremental Gradient Methods; Conjugate Direction Methods; Quasi-Newton Methods; Nonderivative Methods. Optimization over a Convex Set; Lagrange Multiplier Theory; Lagrange Multiplier Algorithms

EDUCATION METHOD

Lectures and exercises

TEXTBOOKS AND LEARNING AIDS

ASSESSMENT

Assessment is	**Written and Oral**	**X**	**Written Only**		**Oral only**		
In case of written assessment, questions are	**Multiple-choice tests**	**X**	**Open questions**	**X**	**Numerical exercises**	**X**	
Other (es: project development, computer test ...)							

POSITIONING AND LOCATION BASED SERVICES

SSD	CFU	Year (I or II)			Semester (I or II)		Language	
		I	II		I	II	Italian	English
ICAR/06	9	X			X			X

Required/expected prior knowledge: NONE

Class(es)				
Teacher(s)				

COURSE OBJECTIVES

The course aims to illustrate key characteristics of positioning and location-based services and provide students with basic concepts, main components, and applications. The focus of the course is the use of real-time and navigation-related measurements applied to mobile positioning and location-based services for all those applications that have strong spatial components and in which object location, proximity and connectivity are the central organizing principle. The course builds on active interaction between theory and practice. The student should collect, process, analyze, and utilize information in the course's subject area.

TABLE OF CONTENTS

Topics of course lectures include:
1. Referencing a position and geodetic data processing, including methods of collection, measurement, computation, analysis, and modelling of geodetic data, particularly in the form of mapping surveys.
2. Representing, organizing, and searching spatial data and object location. Maps and GIS in location-based services.
3. Fundamentals of positioning. Classification of positioning techniques. Basic positioning methods.
4. Satellite navigation. GNSS systems, observations, and data processing.
5. Indoor positioning. Assisted, hybrid, and short-range positioning and navigation: measuring approaches, principles, and technologies. Sensors for ubiquitous navigation and inertial navigation.
6. Mobile positioning and general aspects of location-based services: classification, components, and type of services.

EDUCATION METHOD

Lectures, laboratory activities and exercises

TEXTBOOKS AND LEARNING AIDS

Slides, lecture notes.
Textbooks:
E. Kaplan, C. Hegarty (2017). Understanding GPS/GNSS: Principles and Applications. Artech House Publishers.
J. Schiller, A. Voisard. (2004). Location-Based Services. Elsevier.

ASSESSMENT

Assessment is	**Written and Oral**		**Written Only**		**Oral only**	**X**	
In case of written assessment, questions are	**Multiple-choice tests**		**Open questions**		**Numerical exercises**		
Other	**Laboratory exercises with an oral discussion of the results**						

RAILWAY AND TRANSIT SERVICES

SSD	CFU	Year (I or II)			Semester (I or II)		Language	
		I	II		I	II	Italian	English
ICAR/05	9					X		X

Required/expected prior knowledge: None

Class(es)				
Teacher(s)				

COURSE OBJECTIVES

The course aims to provide students with general concepts relating to the simulation, design and management of railway and transit systems. The different simulation techniques, design methodologies, regulatory aspects and contractual management tools for railway and transit systems are presented.

TABLE OF CONTENTS

- Introduction
  - Concept of modelling
  - Concept of transportation system design
- The simulation of railway and transit services
  - Introduction to simulation
  - Types of vehicles and systems for railway and transit services
  - Signalling systems for railway transportation systems
  - Supply models, flow propagation models, congestion models and cost functions
  - User behaviours for railway and transit systems
  - Simulation techniques and methodologies: assignment, frequency and schedule-based approaches
- Pedestrian movements
  - Introduction: autonomous mode, ait to public transport services, aid to the private car system
  - Pedestrian speed, pedestrian distance, areas of influence and concept of the potential user;
  - Fundamental relationship of pedestrian flow, unit of measurement and concept of pedestrian space;
  - Dimensioning of a walkway, dimensioning of the elements of a railway station (platform);
  - The behaviour of users at railway platforms
- The design of railway and transit services
  - “What if” approach and “what to” approach
  - Variables (decisional and descriptive ones), constraints (technical, external and assignment ones) and objectives (efficiency, effectiveness, quality and objective functions)
  - The design with an optimisation approach: the service frequency definition
  - The design with a simulation approach. definition of the initial configuration (current scenario, project scenario, target scenario)
  - Load diagrams of railway and transit lines;
  - User typologies of the railway and transit services: captive and non-captive users
- Regulatory and organisational aspects for local public transport
  - Concept of local public transport
  - The European Union, the Italian and the Campania Region legislation;
  - Bid procedures and service contracts (gross cost and net cost);
  - Reliability, safety and security of railway and transit services;
  - Quality: quality typologies (expected, planned, provided and perceived qualities), quality management phases. Quality in the local public transport services
- Decision Support Systems
  - G.I.S. software: main features
  - Transportation system simulation software: main features
  - Notes on hybrid software, examples of commercial software
  - The use of railway simulation software (e.g. OpenTrack) for determining rail timetable, rail line capacity and train running times
  - The use of transportation simulation software (e.g. Visum) for determining passenger flows on railway and transit lines (frequency and schedule-based approaches)

EDUCATION METHOD

Lectures (55% of the course), laboratory activities and exercises (45% of the course)

TEXTBOOKS AND LEARNING AIDS

Slides, lecture notes, technical papers. Textbooks: Hansen I. A. and Pachl J. (2008) Railway timetable & traffic: Analysis, modelling, simulation. Eurail Press, Hamburg, Germany. Cascetta E. (2009) Transportation systems analysis: Models and applications. Springer, New York (NY), USA.

ASSESSMENT

Assessment is	**Written and Oral**		**Written Only**		**Oral only**	**X**	
In case of written assessment, questions are	**Multiple-choice tests**		**Open questions**		**Numerical exercises**		
Other (es: project development, computer test ...)							

REAL-TIME SYSTEMS

SSD	CFU	Year (I or II)			Semester (I or II)		Language	
		I	II		I	II	Italian	English
ING-INF/05	9		X			X		X

Required/expected prior knowledge: None

Class(es)				
Teacher(s)				

COURSE OBJECTIVES

The course provides essential knowledge and skills about operating systems and programming for real-time systems used in industrial domains, particularly the automotive sector. It provides the skills needed to design, tune and develop real-time systems, with practical sessions on several environments, such as real-time Linux and FreeRTOS.

TABLE OF CONTENTS

Introduction. Real-time systems: application fields, dimensioning, deadline, hard and soft real-time systems, the role of Real-Time Operating Systems (RTOS).

Background. Operating systems: basic notions and functions. Scheduling, memory management, file system, input/output. Examples of programming multithreaded applications in Linux.

Computer architectures and predictability. Microcontrollers and embedded systems. Non-determinism sources in hardware and software.

Real-time scheduling. Scheduling of aperiodic and periodic tasks. Cyclic executive. Rate Monotonic. Deadline Monotonic. Earliest Deadline First. Feasibility Analysis.

Resource Management. Mutual Exclusion and Semaphores. Priority Inversion. Priority Inheritance and Priority Ceiling.

Real-time networking. The ISO/OSI Stack. Real-time traffic models and sources of non-determinism in networks. CSMA/CD and Token Ring protocols. Controller Area Network (CAN).

Real-Time Operating Systems. Primitives for programming concurrent applications in real-time environments. Input/Output. Examples of RTOS. Focus on real-time Linux and FreeRTOS.

The Automotive context. Standards: OSEK, AUTOSAR, MISRA C, ISO 26262. Practical examples and applications.

EDUCATION METHOD

Lectures (65% of the course), laboratory activities and exercises (35% of the course)

TEXTBOOKS AND LEARNING AIDS

Slides, lecture notes, technical papers.
Textbooks:
G. Buttazzo: "Hard-Real-Time Computing Systems: Predictable Scheduling Algorithms and Applications", Third Edition, Springer

ASSESSMENT

Assessment is	Written and Oral	X	Written Only		Oral only	

In case of written assessment, questions are	Multiple-choice tests		Open questions		Numerical exercises	
Other (es: project development, computer test ...)						

RESILIENCE OF GEOTECHNICAL SYSTEMS

SSD	CFU	Year (I or II)			Semester (I or II)		Language	
		I	II		I	II	Italian	English
ICAR/07	6	X				X		X

Required/expected prior knowledge: none

Class(es)				
Teacher(s)				

COURSE OBJECTIVES

The resilience of any engineering system against extreme environmental events can be defined based on four properties: robustness, redundancy, rapidity, and resourcefulness. Robustness refers to the strength of systems to withstand a given level of demand without suffering a loss of functionality. Redundancy indicates the presence of elements designed to fail without significant effects on the system's overall performance. Rapidity is the capacity to recover the properties of the engineering system timely to contain losses. Resourcefulness is the capacity to identify damages, establish priorities, and mobilize resources for the interventions.
Resilient based-design strategies of geotechnical systems (i.e. those made by soil or interacting with it) aim to improve their robustness and redundancy. Real-time monitoring systems can quickly assess their performance after an extreme event, hence improving the rapidity and resourcefulness.
The course focuses on the key aspects of the performance of some geotechnical systems typically employed in the road and railway infrastructures, such as embankments, retaining structures and foundations of viaduct piers, against extreme meteorological and seismic events. The technologies currently suitable to monitor their performance and the interventions to improve it are illustrated and discussed regarding robustness, redundancy, resourcefulness, and rapidity.

TABLE OF CONTENTS

Engineering Resilience

- Definition: the concept of resilience applied to infrastructures; robustness, redundancy, rapidity and resourcefulness.
- Resilience assessment methods: system functionality function: basic concept; definition of intensity measures for extreme natural events and engineering demand parameters; fragility curves.

Earth structures: embankments and slopes

- Construction: geometrical features of embankments and slope cuts; compaction, pre-loading and excavation procedures.
- Stability: mechanisms and kinematics of natural or artificial slope instability; the role of pore pressure; Limit Equilibrium Methods of analysis.
- Performance and interventions: settlements due to self-weight and additional loads; effects on pavements; mitigation techniques.
- Monitoring: use of inclinometers and optical fibres; pore pressure measurements for stability; use of ground surface levelling and satellite surveys for settlements; monitoring of seismic or hydrological intensity measures to estimate the expected damage.

Retaining structures

- Construction: earth pressure: basic concepts; gravity structures (masonry or unreinforced concrete walls, r.c. cantilever walls); embedded structures (cast-in-place cantilever walls, pre-cast bulkheads); anchors and props.
- Stability: Rankine earth pressure theory; forces equilibrium-based solutions; the role of pore pressures; mechanisms and kinematics of rigid and flexible wall ultimate states; Limit Equilibrium Methods of analysis.
- Performance and interventions: empirical and simplified methods for predicting settlements and horizontal displacements; effects on roads and railways; mitigation techniques.

EDUCATION METHOD

Lectures, laboratory activities and exercises, project development

TEXTBOOKS AND LEARNING AIDS

Slides, lecture notes, technical papers.

ASSESSMENT

Assessment is	**Written and Oral**		**Written Only**		**Oral only**	**X**
In case of written assessment, questions are	**Multiple-choice tests**		**Open questions**		**Numerical exercises**	
Other	Discussion of lab activities and developed project					

Teaching: Resilience of Transportation Systems							
CFU: 6			SSD: ICAR/05				
Hours for frontal lessons: 22			Hours for applications: 26				
Year: (I-II MSc)							
Learning outcomes: The course deals with the resilience of transport infrastructures. Starting from local aspects due to service stress, ageing deterioration and rare catastrophic events, the effect on networks and broad areas is estimated/forecasted, including the impact in terms of social and economic terms.							
Contents: • General Principles • Theory of transportation systems applied to transportation resilience. ▪ local impact ▪ extended disruption (network impact) • Network re-configuration effects ▪ Dynamic processes toward a new equilibrium ▪ Instability • Wide-area KPI (Key Performance Indicators) ▪ Area-wide accessibility ▪ Transport times/costs ▪ Social and economic effects • Practical approaches ▪ Methods and tools based on traffic assignment matrices. ▪ Identification of the “strategic” network (transportation infrastructures and services to preserve • Laboratory activities and exercises, project development							
Code:			Semester: II				
Prerequisites: none							
Teaching method: Lectures, laboratory activities and exercises, project development							
Teaching material: Slides, lecture notes, technical papers							
Examination procedures: The final examination consists of an oral exam covering the theoretical and technical aspects described within the course and discussing developed projects.							
The exam is divided into tests:	Written and spoken		Only written		Only spoken	x	
In the case of a written test, the questions are:	Multiple-choice		Essay questions		Exercises		
Other:	Discussion of lab activities and developed project						

ROAD SAFETY

SSD	CFU	Year (I or II)			Semester (I or II)		Language	
		I	II		I	II	Italian	English
ICAR04	9	X				X		X

Required/expected prior knowledge: none

Class(es)				
Teacher(s)				

COURSE OBJECTIVES

The course's main objective is to train road safety experts, transfer skills to manage the safety management process, determine countermeasure options from thorough information analysis, and prioritise and evaluate countermeasure implementation programs. The course covers procedures for highway safety management. It includes network screening, diagnosis, selection and prioritization of countermeasures. Students acquire fundamental knowledge on the advanced safety management tools required by the EU Directive on road infrastructure safety management, such as road safety impact assessment, road safety audits and road safety inspections.

TABLE OF CONTENTS

- Crash data
  - Characteristics of crashes
  - Traffic conflicts
  - Measurement of road safety
  - Crash databases
- Highway safety plans
  - Highway safety vision
  - Highway safety management pillars
  - UN Global Plan for the Decade of Action for Road Safety 2011-2020
  - EU policy orientations on highway safety
  - US strategic highway safety plan
- Safety performance functions
  - Equations to estimate the expected crash frequency (including by crash severity and collision types) of a network, facility, or individual site
  - Model form and data needs
  - Error distribution
  - Dispersion parameter
  - Goodness of Fit measures
  - Highway Safety Manual models
- Network screening
  - General issues
  - Regression to the mean
  - Crash frequency
  - Equivalent property damage only
  - Crash rate, critical crash rate
  - Proportion method
  - Empirical Bayes method
  - Potential for safety improvement
  - Comparison among the methods
  - Exercises
- Diagnosis
  - Crash contributory factors
  - Crash data analysis
  - Crash patterns analysis
  - Site inspections
  - Case studies
  - Exercises
- Selection of countermeasures

- Criteria for the selection of the countermeasures
- Countermeasures for intersections
- Countermeasures for segments
- Countermeasures for high-risk road users
- Exercises

- Economic appraisal and prioritisation
  - General issues
  - Crash modification factors (segments and intersections)
  - Crash costs
  - Benefits of countermeasures
  - Costs of countermeasures
  - Prioritisation criteria
  - Safety effectiveness evaluation
  - Exercises
- Road safety inspections
  - Standards, procedure
  - Checklists (master checklists, detailed checklists, checklists for pedestrians, checklists for cyclists, checklists for roadworks)
  - Quantitative safety evaluation (rural two-lane highways, at-grade intersections, roundabouts, pedestrian crossings, roadworks)
  - Network safety management based on road safety inspections
  - Case studies
  - Exercises
- Road safety impact assessment
  - Background
  - Definition
  - Aims for new and old roads
  - Procedure
  - Examples and case studies
- Road safety audits
  - Background
  - Definition
  - Aims and benefits
  - Implementation stages
  - Procedure
  - Key issues to consider
  - Legal implications
  - Audit tools
  - Examples and case studies

EDUCATION METHOD

Lectures, tutorials, exercises, and project work.

TEXTBOOKS AND LEARNING AIDS

Slides.

AASHTO (2010). Highway Safety Manual, First Edition.

Cafiso S., La Cava G., Montella A., Pappalardo G. (2008). Operative Procedures for Safety Inspections on Two-Lane Rural Roads. Available at http://ec.europa.eu/transport/roadsafety_library/publications/iasp_safety_inspections_manual_en.pdf

Lord D., Washington S., Montella A. et al. (2018). Safe Mobility: Challenges, Methodology and Solutions. Emerald Publishing.

ASSESSMENT

Assessment is	**Written and Oral**	**X**	**Written Only**		**Oral only**		
In case of written assessment, questions are	**Multiple-choice tests**		**Open questions**	**X**	**Numerical exercises**	**X**	
Other (es: project development, computer test ...)	Project development and computer test						

SMART ROADS AND COOPERATIVE DRIVING

SSD	CFU	Year (I or II)			Semester (I or II)		Language	
		I	II	III	I	II	Italian	English
ICAR/05	6		X			X		X

Required/expected prior knowledge: NONE

Class(es)				
Teacher(s)				

COURSE OBJECTIVES

The course provides students with a clear and deep understanding of the technical and functional requirements to be satisfied for vehicle/road interaction in connected and automated driving scenarios.

TABLE OF CONTENTS

- General Principles
  - Autonomous driving and cooperative driving
  - From autonomous driving to automated driving
  - Historical overview of autonomous/automated driving development for surface vehicles and state of the art
- Cooperative-Intelligent Transportation Systems platforms and services
  - Opportunities, criticalities, regulation and technical/functional requirements
  - Road-side implementation of cooperative driving
  - On-board implementation of cooperative driving
  - European C-ITS platform and services
  - Day 1 services and further services
  - Overview of specific (cyber)security issues
- Impacts on vehicular traffic
  - Automated, connected and mixed traffic
  - Interaction of connected vehicles and automated vehicles with existing transportation systems
  - Interaction and synergies with Mobility-as-a-service solutions
- Design of cooperative-driving solutions and mobility solutions in a simulation environment

EDUCATION METHOD

Lectures, laboratory activities and exercises.
The proposition of practical applications for the learned concepts receives particular attention: To this aim, the course also hosts lectures and seminars with experts from the field of road and traffic operators and authorities.

TEXTBOOKS AND LEARNING AIDS

Slides, lecture notes, technical papers, regulation documents.

ASSESSMENT

Assessment is	**Written and Oral**	**X**	**Written Only**		**Oral only**		
In case of written assessment, questions are	**Multiple-choice tests**	**X**	**Open questions**		**Numerical exercises**	**X**	
Other (es: project development, computer test ...)							

STATISTICAL LAB FOR INDUSTRIAL DATA ANALYSIS

SSD	CFU	Year (I or II)			Semester (I or II)		Language	
		I	II		I	II	Italian	English
SECS-S/02	9	X			X			X

Required/expected prior knowledge: none

Class(es)				
Teacher(s)	**Antonio Lepore**			

COURSE OBJECTIVES

Statistical Lab for Industrial Data Analysis is a problem-based learning course aiming to train students on the application (illustrated through open-source statistical software environment R) of interpretable statistical techniques for decision-making, possibly scalable also up to big data frameworks.
Every student must choose a data analysis project gathered along the course by experts in industrial engineering and develop it by working in a team. The industrial engineering experts may want to participate in initial, intermediate and final workshops, where student groups show their project work in progress. In this way, students have the opportunity to improve their ability to recognise and implement the most suitable statistical techniques to the problem at hand and communicate relevant results and the impact of their analysis to non-statisticians.

TABLE OF CONTENTS

- Overview and course objectives.
- Description of multivariate data and inference about mean vectors.
- Elements of unsupervised learning
  - Principal component analysis
  - Clustering methods
- Elements of supervised learning
  - Problems in multivariate linear regression models
  - Linear model selection and regularization (ridge regression, the lasso)
  - Reduction methods (principal components regression, partial least squares)
  - Overview of classification methods
- Statistical process monitoring and control
  - Control charts for variables and attributes
  - The Hotelling control chart
  - Regression adjustment
  - Interpretation of out-of-control signals.
- Beyond multivariate data analysis
  - Introduction to functional data analysis
  - Statistical monitoring of functional data.
  - Engineering examples through software environment R.

EDUCATION METHOD

Lectures, interactive tutorials, laboratory activities and exercises

TEXTBOOKS AND LEARNING AIDS

Johnson, R.A. and Wichern, D.W., (2007). Applied Multivariate Statistical Analysis (6th edition), Prentice-Hall, Upper Saddle River
D. Montgomery, (2014) Introduction to Statistical Quality Control. 7th edition. John Wiley & Sons
James, G., Witten, D., Hastie, T., & Tibshirani, R. (2013). An introduction to statistical learning. New York: Springer.
MOOC Industry 4.0 Big Data e Data Analytics III - a cura di B. Palumbo e M. L. Chiusano (2019) https://landing.federica.eu/industria40/

ASSESSMENT

Assessment is	**Written and Oral**	**X**		**Written Only**		**Oral only**	

In case of written assessment, questions are	**Multiple-choice tests**		**Open questions**		**Numerical exercises**		
Other (es: project development, computer test ...)	Project development						

SUSTAINABLE ROAD MATERIALS

SSD	CFU	Year (I or II)			Semester (I or II)		Language	
		I	II		I	II	Italian	English
ICAR/04	9					X		X

Required/expected prior knowledge:

Class(es)				
Teacher(s)				

COURSE OBJECTIVES

The course provides extensive knowledge and analysis methodologies to design asphalt blends for bearing and base layers of a road/railway pavement and for the subbase unbound layers, focusing on all laboratory tests and on-situ procedures for accepting the mixtures. Rigid pavements are also analyzed, dealing with general principles for laying runways and airport aprons.
One of the main scopes is addressed to the mix design of traditional bituminous blends (hot mix asphalt) and alternative ones where a) virgin aggregates are replaced partly or totally with waste or local resources, b) neat bitumen is modified with polymers, c) warm-cold production technologies are used.
The study program is structured to provide theoretical knowledge and practical tools oriented to a sustainable approach for designing and testing road pavements blends, comparing different scenarios of production, construction, and maintenance to a reference case involving the use of common paving materials; mechanical performance and life cycle assessment (LCA) is investigated.
This way, it is possible for the students to accomplish the course's main objectives, focused on methodological-laboratory approach for designing road pavement mixture, promoting advanced maintenance management support systems and an "end-of-waste" vision into the whole design process.

TABLE OF CONTENTS

- General principles
  - Historical Developments
  - Pavement Types
  - Design Factors
  - Design Procedures
  - Equivalent Single-Wheel Load
  - Equivalent Axle Load Factor
- General principles of Flexible Pavement Design
  - Mechanistic Design Procedure
  - Asphalt Institute Method
  - AASHTO Method
- Rigid Pavement Design
  - Mechanistic Design Procedure
  - AASHTO Method
  - Continuous Reinforced Concrete Pavements
- asphalt binder
  - Chemical composition of asphalt
  - asphalt binder tests
  - Superpave binder ageing procedures (Rolling Thin Film Oven, Pressure Aging Vessel)
  - Superpave binder tests (Dynamic Shear Rheometer, Rotational Viscometer, Bending Beam Rheometer, Direct tension Tester)
- binder grade selection
  - Superpave performance grades
  - Air temperature selection
  - Binder grade selection Based on Pavement Temperatures
  - Adjusting Binder Grade Selection for Traffic Speed and Loading
- Superpave Mix Design
  - Test equipment: Superpave gyratory compactor
  - Select design aggregate structure
  - Specimens preparation and compaction

– Data analysis
– Design asphalt binder content
– Moisture sensitivity
• Marshall Mix Design
– Test equipment: Marshall Impact Compactor
– Select design aggregate structure
– Specimens preparation by selecting at least four percentages of binder and compaction
– Marshall Stability curve
– Marshall Flow curve
– Design asphalt binder content
• Asphalt Mixture volumetrics
– bulk specific gravity
– apparent specific gravity
– effective specific gravity
– maximum specific gravity
– voids in mineral aggregate
– effective asphalt content
– voids filled with asphalt
• Material Characterization of asphalt mixtures
– Indirect Tensile Strength
– Dynamic Modulus of Bituminous Mixtures
– Fatigue Characteristics
– Permanent Deformation Parameters
– Other Properties
• Stresses and Strains in Flexible Pavements
– Theory of Elastic Layer Systems
– Comparison with Available Solutions
– Computer program
• Reusing secondary raw materials
– practices and methods for testing the effects of polymer modified binders and polymer modified asphalt
– practices and methods for testing the effects of waste into asphalt mixtures
• Pavement Performance Evaluation
• General Principles of Life Cycle Assessment
– Definition of the four LCA Phases
– Performing an LCA
– Comparison of LCA with other environmental analysis tools
• Inventory analysis of Emissions and Extraction
– principles of inventory analysis
– calculation and assessment of energy consumption and CO2 emissions
– input-output approach for extractions and emissions inventory
– coproducts and allocation
• Life cycle Impact Assessment
– purpose and general principles
– steps of impact assessment: classification, midpoint characterization, damage characterization, normalization, grouping, weighting
– overview of the main Impact Assessment Methods
• Interpretation of results
– Identification of priorities
– Uncertainty, variability and data quality
– Sensitivity study
– Application to product comparisons
– Application to long term decision-making

EDUCATION METHOD

Lectures, interactive tutorials, laboratory activities and exercises

TEXTBOOKS AND LEARNING AIDS

Slides, lecture notes, technical papers. Textbooks: Yang H. Huang, Pavement Analysis and Design, Pearson, 2003. Asphalt Institute, SUPERPAVE Performance Graded Asphalt Binder Specification and Testing, Superpave Mix Design. Superpave Series No. 1-2, 1997. Faiq M. S. Al-Zwainy, Esam Hewayde, Firas Jaber, Pavement Maintenance and Management, Lulu Press, 2020. Olivier Jolliet, Myriam Saade-Sbeih, Shanna Shaked, Alexandre Jolliet, Pierre Crettaz. Environmental Life Cycle Assessment, CRC Press; 1st edition (November 18, 2015)

ASSESSMENT

Assessment is	**Written and Oral**	**X**	**Written Only**		**Oral only**		
In case of written assessment, questions are	**Multiple-choice tests**		**Open questions**		**Numerical exercises**		
Other (es: project development, computer test ...)	**Project development and computer test**						

Systems and Control Fundamentals

SSD	CFU	Year (I or II)			Semester (I or II)		Language	
		I	II		I	II	Italian	English
ING-INF/04	9	X	X		X			X

Required/expected prior knowledge: none

Class(es)				
Teacher(s)	**Prof. Stefania Santini**			

COURSE OBJECTIVES

Feedback control is a remarkably pervasive engineering principle. Feedback control uses sensor data (e.g. position, velocity, acceleration) to adjust or correct actuation (e.g. steering angle, motor acceleration). The subject is an uncommonly compelling example of mathematical theory guiding practical design. Hence, the training objective is to introduce students to the design and analysis of mathematical models and their use for predicting the dynamic behaviour of linear and non-linear systems and for deriving control algorithms.
This engineering course introduces the theory and practice of feedback control and provides a glimpse into the subject. The final aim is to learn the basics of systems analysis and control design.

TABLE OF CONTENTS

1. Introduction
2. Mathematical Foundations
3. Systems fundamentals:
   - Models for Linear Dynamical Systems.
   - State-Space models.
   - Analysis Methods.
   - Stability of linear systems.
   - Analysis and Design Methods for Nonlinear Systems.
   - Stability analysis of non-linear systems. Linearization. Lyapunov Theory; Case Studies.
   - Software for Modeling and Simulating dynamical Systems.
4. Linear Control fundamentals:
   - Introduction to control; Motivating examples; Definition of a control problem.
   - Single-input, single-output control essentials.
   - From open- to closed-loop control architectures.
   - Robustness issue concerning additive disturbances.
   - State Feedback Control and control tuning via Pole-Placement technique.
   - State Observers. Combining state feedback control with an observer.
   - Output Feedback Control: PID and Relè Control.
   - Case Studies.
   - Computer-aided control systems design.
   - Software for modelling and simulating Control Systems.

EDUCATION METHOD

Lectures, interactive tutorials, laboratory activities and exercises.

TEXTBOOKS AND LEARNING AIDS

Slides, lecture notes, technical papers.
Textbooks: Gene F. Franklin, J. David Powell, Abbas Emami-Naeini, Feedback Control of Dynamic Systems (Inglese), ISBN-10: 0133496597.

ASSESSMENT

Assessment is	**Written and Oral**	**X**	**Written Only**		**Oral only**	

In case of written assessment, questions are	**Multiple-choice tests**		**Open questions**		**Numerical exercises**		
Other (es: project development, computer test ...)	Project development and computer test						

TESTING AND VALIDATION OF AUTOMATED ROAD VEHICLES

SSD	CFU	Year (I or II)			Semester (I or II)		Language	
		I	II		I	II	Italian	English
ICAR/05	9	X	X		X			X

Required/expected prior knowledge: NONE

Class(es)				
Teacher(s)				

COURSE OBJECTIVES

The course provides students with theoretical and technical skills for the validation of automated vehicles in simulation environments

TABLE OF CONTENTS

- Definition of testing and validation scenarios
- Automation levels, use cases and operational design domain
- Traffic modelling
  - Static vs adaptive/responsive approaches
  - Traffic micro-simulation, integration of detailed vehicle logics and nano-simulation approaches
  - Integration of adaptive/responsive traffic models in complex vehicle-simulation environments
- Adoption of vehicle-automation logic and integration in the modelling framework
  - Model-in-the-loop framework
  - Integration with traffic operator services
  - Integration with driving simulation environments
- Testing strategies
  - Use case vs continuous testing
  - Sensitivity analysis
- Experiences and experiments

EDUCATION METHOD

Lectures, interactive tutorials, laboratory activities and case studies, project developing, learning-by-doing, challenge-based learning

TEXTBOOKS AND LEARNING AIDS

Slides, lecture notes, technical papers, lab activities, learning-by-doing, and challenge-based learning

ASSESSMENT

Assessment is	Written and Oral		Written Only		Oral only	X

In case of written assessment, questions are	Multiple-choice tests		Open questions		Numerical exercises	
Other (es: project development, computer test ...)	Project development					

TRAFFIC CONTROL

SSD	CFU	Year (I or II)			Semester (I or II)		Language	
		I	II		I	II	Italian	English
ICAR/05	9		X		X			X

Required/expected prior knowledge:

Class(es)				
Teacher(s)				

COURSE OBJECTIVES

The course aims to provide students with the knowledge and operational tools for analysing, simulating, designing, and managing urban and freeway traffic control systems.

TABLE OF CONTENTS

- Basic Notions
  - System and models; Control-loop elements; Open-loop vs. Closed-loop control; the Regulation Problem; Optimal Control Strategies; Optimisation Theory; Heuristics.
- Traffic Flow Modelling
  - Traffic fundamentals: Definitions; Speed-flow relationship and Fundamental Diagram; Conservation Equation; Edie's traffic variable definitions; Space mean speed and Time mean speed; Macroscopic fundamental diagram;
  - Microscopic Models: Car-following equations; Stability of a string of vehicles; Lane-changing models; Microscopic simulation tools;
  - Macroscopic Models: Kinematic waves and shock waves; LWR model; CTM model; Drivers' anticipation; Second-order models; Modelling of on-ramp flow;
  - Uncertainty modelling: Model Calibration, Global Sensitivity Analysis, Model Validation.
- Modelling of Traffic Networks
  - Traffic Assignment: Basic Notions; User and System Optimality; Braess paradox; Stochastic traffic assignment; Day-to-day dynamics;
  - Dynamic Traffic Assignment: Time-dependent travel times; Microscopic, mesoscopic, and macroscopic dynamic traffic assignment; Splitting rates; Instantaneous and experienced travel time.
- Measurement and Estimation
  - Measurement Devices: Loop detectors; Traffic occupancy; Magnetic sensors; Ultrasonic detectors; Video sensors; Video image processing; P2P measurements; Average travel time; Floating car surveys;
  - Estimation of Traffic Variables;
  - Origin-Destination Matrix Estimation: Problem statement; Static O-D estimation; Dynamic O-D estimation; Kalman Filter application.
- Freeway Traffic Control
  - Introduction: Capacity drop; Control measures; Basic problems;
  - Ramp Metering; Fixed-time ramp metering using Linear and Quadratic Programming; Local ramp metering strategies; ALINEA;
  - Link Control: Variable speed limits (VSL); Optimal VSL control; SPECIALIST; Reversible flow;
  - Merging and Mainstream Traffic Control;
  - Freeway traffic management in the presence of VACS - Vehicle Automation and Communication Systems; Research needs.
- Road Traffic Control
  - Basic definitions; Groups of lanes, stages, split, cycle, and offset; Classification of control strategies
  - Isolated Intersection Control: Fixed-time strategies; Webster signal settings; SIGSET and SIGCAP; Real-time strategies; Vehicle-interval method; Volume-density method;
  - Fixed-Time Coordinated Control: MAXBAND; MULTIBAND;
  - Coordinated Real-Time Strategies: SCOOT, Store and- forward based approaches: Linear Programming, Quadratic Programming, LQ-regulation; perimeter control.
- Laboratory on Microscopic Simulation (AIMSUN).

EDUCATION METHOD

Lectures, interactive tutorials, laboratory activities and numerical exercises

TEXTBOOKS AND LEARNING AIDS

Slides, lecture notes, technical papers. Textbooks: Treiber, M., Kesting, A., 2013. Traffic flow dynamics: data, models and Simulation, Springer. Daganzo, C.F., 1997. Fundamentals of transportation and traffic operations. vol. 30. Oxford: Pergamon. Saltelli, A., et al., 2008. Global Sensitivity Analysis: The Primer, Wiley.

ASSESSMENT

Assessment is	**Written and Oral**		**Written Only**		**Oral only**	**X**	
In case of written assessment, questions are	**Multiple-choice tests**		**Open questions**		**Numerical exercises**		
Other (es: project development, computer test ...)	Project development and computer test						

TRANSPORTATION GEOTECHNICS

SSD	CFU	Year (I or II)			Semester (I or II)		Language	
		I	II		I	II	Italian	English
ICAR/07	9	X				X		X

Required/expected prior knowledge: A background in Geotechnics is required

Class(es)				
Teacher(s)				

COURSE OBJECTIVES

Safe and sustainable design and maintenance of transportation infrastructures require a sound knowledge of geotechnical problems related to their interaction with the ground. The course aims to illustrate to students the main geotechnical issues related to construction, safety, performance and monitoring of transportation infrastructures. All the above aspects are shown with specific reference to embankments, excavations, retaining structures and tunnels. Both traditional and modern technologies for construction and monitoring are exemplified concerning well-documented case studies and, possibly, with the aid of visits to construction sites. Theoretical lessons focus on up-to-date approaches for assessing safety and performance requirements and are closely related to the code of practice rules. Classroom exercises and tutorials address the students to the application of the most widespread simplified and empirical methods.

TABLE OF CONTENTS

Earth structures: embankments and slopes

- Construction: behaviour of unsaturated and compacted soils; compaction and pre-loading procedures; lightweight construction materials.
- Stability: mechanisms and kinematics of natural or artificial slope instability; the role of pore pressure and soil suction; seepage analysis; Limit Equilibrium Methods of analysis.
- Performance: settlements due to self-weight and additional loads; effects on pavements; mitigation techniques.
- Monitoring: usage of inclinometer, pore pressure and suction measurements for stability; usage of ground surface levelling and satellite surveys for settlements.

Retaining structures

- Construction: earth pressure: basic concepts; gravity structures (masonry or unreinforced concrete walls, r.c. cantilever walls); embedded structures (cast-in-place cantilever walls, pre-cast bulkheads); anchors and props; types of reinforced earth structures; gabions.
- Stability: Rankine earth pressure theory; forces equilibrium-based solutions; the role of pore pressures; mechanisms and kinematics of rigid and flexible wall ultimate states; seepage analysis; Limit Equilibrium Methods of analysis.
- Performance: empirical and simplified methods for predicting settlements and horizontal displacements; effects on buildings; mitigation techniques.
- Monitoring: use of inclinometer and ground surface levelling surveys for horizontal and vertical displacements.

Tunnels

- Construction: excavation techniques (conventional heading; mechanized excavation); lining systems (sprayed or cast-in-situ concrete lining; pre-cast segmental lining).
- Stability: stability of the tunnel face; the role of pore pressures; stresses and deformation around a cavity; ground-support interaction; simplified and continuum analysis methods.
- Performance: ground displacements around tunnel excavation; volume loss; empirical and numerical methods of analysis; tunnel-soil-building interaction; mitigation techniques.
- Monitoring: instrumentations for monitoring lining and ground behaviour during tunnel construction and working conditions; observational method.

EDUCATION METHOD

Lectures, interactive tutorials and exercises, field trips

TEXTBOOKS AND LEARNING AIDS

Slides, lecture notes, technical papers.
Textbooks:
Clayton C.R.I., Milititsky J., Woods R.I., Bond A.J. (2014). Earth pressure and earth-retaining structures (3rd edition). Taylor & Francis - CRC Press.

AA.VV. (2021). Handbook on tunnels. Part 1 – Basic Principles of Design. Taylor & Francis - CRC Press.

ASSESSMENT

Assessment is	**Written and Oral**		**Written Only**		**Oral only**	**X**

In case of written assessment, questions are	**Multiple-choice tests**		**Open questions**		**Numerical exercises**	
Other						

TRANSPORT PLANNING AND APPRAISAL

SSD	CFU	Year (I, II or III)			Semester (I or II)		Language	
		I	II	III	I	II	Italian	English
ICAR05	9		X		X			X

Required/expected prior knowledge: none

Class(es)				
Teacher(s)				

COURSE OBJECTIVES

The course aims to provide general knowledge about the transport planning process considering its several phases, including recognising critical aspects in a transport system, defining goals and targets, identifying different solutions and scenarios and carrying out evaluations. Methods and algorithms for the transportation system simulation in several scenarios, theoretically treated in other courses, are introduced from an application standpoint. The course focuses on the leading indicators to be estimated to address the evaluation of a project and/or a plan concerning environmental and other "external" aspects. The main comparison and evaluation techniques, as cost-benefits analysis and multicriteria analysis, are presented and applied to a case study.

TABLE OF CONTENTS

- Transportation system
  - General definitions of demand and supply systems
  - Travel demand estimation
  - Traditional survey and Big Data
  - Transport supply simulation
  - Freight transportation models
  - Demand and supply interactions
  - Evaluation of transport systems performances
- Planning scenarios
  - Current scenario
  - Time horizon for future scenarios
  - Business as usual scenario (BAU)
  - Recognition of critical issues and definition of objectives
  - Definition of alternatives scenarios
- Project evaluation
  - Investment costs estimate
  - Maintenance costs estimates
  - Management costs estimates
  - Incomes estimates
  - Transportation analysis
  - Financial analysis
  - Benefits estimate
- Decision-making process
  - Italian guidelines for evaluation of public investment
  - Other countries evaluation guidelines
  - Infrastructure investment evaluation
  - Rating system of the sustainable infrastructures - Envision protocol
  - Public engagement
- Wider economic impacts
  - Environmental impacts
  - Pollutant emission
  - Accidents forecasting
  - Primary sources consumption
  - Land use
  - Impacts on the job market
  - Life cycle assessment

- Carbon footprint
- Evaluation techniques
  - Costs-benefits analysis
  - Multi-criteria analysis
- Software packages for transport system simulation
- Sensitivity analysis
- Risk analysis
- Before and after analysis

EDUCATION METHOD

Lectures, interactive tutorials, laboratory activities and exercises

TEXTBOOKS AND LEARNING AIDS

Slides, lecture notes, technical papers. Textbooks:
Transportation Systems Engineering Theory and Methods – Ennio Cascetta - Springer

ASSESSMENT

Assessment is	**Written and Oral**		**Written Only**		**Oral only**	**X**	
In case of written assessment, questions are	**Multiple-choice tests**		**Open questions**		**Numerical exercises**		
Other (es: project development, computer test ...)	**Project development**						

TUNNELS AND UNDERGROUND STRUCTURES

SSD	CFU	Year (I or II)			Semester (I or II)		Language	
		I	II		I	II	Italian	English
ICAR/07	9	X				X		X

Required/expected prior knowledge: A background in Geotechnics is required

Class(es)				
Teacher(s)				

COURSE OBJECTIVES

Due to the increased social demand for sustainable mobility in large urban areas, underground works involving tunnelling in densely urbanised areas have increased in recent years. The course aims to illustrate the main geotechnical issues related to tunnelling and underground construction, particularly in urban areas. The fundamentals of tunnel design and the most common methodologies for tunnel construction are presented with the aid of documented case histories. Besides attending the theoretical lessons, students are involved in applied activities consisting of exercises reflecting the state-of-practice of geotechnical design of tunnels

TABLE OF CONTENTS

Geotechnical Investigation for Tunnel Construction. Investigations at typical stages of a tunnel project. Rock rating and classification. Special tests for TBM excavation.
Tunnel Stability. Limit analysis theorems. Stability of a plane strain circular opening in drained and undrained conditions. Stability of circular heading in drained and undrained conditions. Local stability. Stability of openings in the rock mass.
Tunnel Construction Techniques. Heading. Drill and blast excavation. Open face excavation. Tunnelling shields and Tunnel Boring Machines. Cut and cover tunnelling. Tunnelling waste and muck removal.
Stresses around Tunnels. Stresses and deformation around an elastic cavity. Plane strain and axisymmetric conditions supported and unsupported cavity in isotropic primary stress. Anisotropic primary stress. Anisotropic elastic ground. Circular cavity in elastoplastic ground. Ground and Support Reaction Lines. Stresses around tunnel heading. Stresses around a spherical cavity.
Principles of Tunnel Lining Design. Arching. Ground-support interaction: continuum methods, bedded-spring models, convergence-confinement method. Examples of calculation methods.
Lining systems. Sprayed Concrete Lining. Cast-in-situ concrete lining. Pre-cast segmental lining.
Ground Improvement Techniques. Ground Reinforcement. Ground Freezing. Grouting.
Ground Movements. Sources of ground movement around tunnel excavation. The empirical method of prediction. Analytical methods. Numerical methods: effects of soil nonlinearity, anisotropy, slight strain stiffness, and recent stress history. Influence of the building stiffness on the settlement profile, modification factors. Evaluation of relative stiffness parameters for masonry bearing walls, framed structures, façades with openings. Assessment of risk of damage to buildings. Protective measures: in-tunnel measures, ground treatment, compensation grouting, barriers.
Seismic Behaviour of Tunnels and Underground Structures. Seismic behaviour and damage of cylindrical long underground structures (tunnels and pipelines): examples. Damage patterns and classification. Fragility curves. Fundamentals of seismic site response analysis. Methods of analysis: transversal section, coupled and uncoupled approach; simplified methods; analysis in the longitudinal direction.
Monitoring and control in Tunnel Construction. Quality of measure. Types of instrumentations for tunnel construction. Observational method. Examples

EDUCATION METHOD

Lectures, Classworks, Tutorials, Seminars on Case studies, Site visits

TEXTBOOKS AND LEARNING AIDS

- Lecture notes and slides
- D.Kolymbas, Tunnelling and Tunnel Mechanics, Springer
- D. Chapman et al., Introduction to Tunnel Construction, Spon Press

ASSESSMENT

Assessment is	**Written and Oral**		**Written Only**		**Oral only**	**X**	
In case of written assessment, questions are	**Multiple-choice tests**		**Open questions**		**Numerical exercises**		
Other	Discussion on classwork						