HECTOR SCHOOL
Technology Business School of the KIT

Karlsruher Institut für Technologie

Course Guide Book Intake 2020/2021

Executive Master Program
Mobility Systems Engineering & Management

Contents

Contact & Imprint

HECTOR School of Engineering and Management, Karlsruhe Institute of Technology (KIT)

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1 Foreword

Current Trends and Challenges in Mobility Systems Engineering and Management

Electronic systems are omnipresent. Currently they range from portable devices such as digital watches and smart phones to large stationary installations like traffic lights, factory controllers or the systems controlling of power plants. Communication - stationary or over-the-air – of these particular systems form a network of control, sensing and influencing the environment. A cyber physical system is the result.

These trends fundamentally influence industry (“industry 4.0”) and mobility, mainly vehicles for automated driving, electrical drive trains and car-2-x communication. As a consequence, sustainable mobility concepts are increasingly using embedded electronic systems to maximize efficiency, enable automation and reduce pollution.

New processes, methods and tools of systems engineering are needed to design and validate these networks of embedded systems. Agile programming (e.g. SCRUM) for self-learning functions up to artificial intelligence will find its way into conservative mechanical engineering and enhance the more or less established life cycle models such as the “V”. In addition, validation will step beyond X-in-the-Loop and demand for data analytics of a large number of sensor data. But what is the right method for the right challenge? Am I using the appropriate tool or am I horribly over-loading the simple task? Assessments will answer these questions, currently we rely on CMMI and SPICE, which will surely be enhanced for the upcoming hypes.

Electronic systems are designed to do some specific tasks, rather than be a general-purpose computer for multiple tasks. Some also have real-time performance constraints that must be met, for reasons such as safety and usability; others may have low or no performance requirements, allowing the system hardware to be simplified to reduce costs. Standards (e.g ISO 26262 for functional safety) will influence the design decision process.

Reducing the size and cost of the product, increasing the reliability and performance of electronic components such as sensors and controllers enables more and more digital applications. The story goes on.

As a consequence, the demand for innovations by society and the raise of new technologies in universities and large scale research institutions offer tremendous opportunities to overcome “historic” electronic development thinking. The Master Program in Mobility Systems Engineering and Management offers a unique combination of courses in emerging technologies, systems engineering know-how and methods as well as management tools tailored for the challenges of mobility. Those are: e-drive, auto-drive, communication-over-the-air, worldwide release and configuration management.

With its long tradition in mobility, electrical, information and communication programs, Karlsruhe Institute of Technology (KIT) provides an ideal environment. Building on the long-established

reputation for excellence in business engineering, our master program combines an in-depth knowledge and understanding of fundamental concepts in business, finance and management with the latest developments in Electronic Systems Engineering.

Graduates of the MSEM program will be able to analyze, design and optimize electronic systems with state-of-the art technologies. As project managers they will be able to evaluate the objective of the development engineers, namely on the optimization of heterogeneous and integrated systems regarding production costs, reliability and performance. This would be in accordance with the project and corporate goals. The skills acquired within this M.Sc. degree program encompasses state-of-the-art technology know-how ranging from the component level (Physical Layer) to the module and system level. Participants will be capable of applying methodological tools for integrated product development within innovation processes and to implement and transfer the methods from a TQM approach to the processes of electronic product development. They will be familiar with the preparation and optimization of strategic business decisions.

Graduates will be able to analyze and evaluate mechatronic product development in relation to economic parameters. They will understand the systems approach behind financial and management accounting and to apply it for controlling purposes within corporate management. They will become familiar to prepare the necessary information on which decisions regarding strategic management will be based and implement them. They are able to integrate team members with different backgrounds due to their multidisciplinary education. Development of new products of part of them is a heterogeneous task. Teams spread all over the world contribute to the final product and the product itself is not more a result of one discipline only. It is an overall system combining mechanical, electrical and electronical parts and communications with nearly everything. This demands not only new methods, tools, but new thinking.

Join us to acquire your tools that will guide your career in this exciting area.

Prof. Dr.-Ing. Eric Sax

Program Director for Mobility Systems Engineering and Management

2 Program Directors

Title/Name	Prof. Dr.-Ing. Eric Sax	
Phone	+49 (0) 721 608 42500	
E-Mail	***Eric.Sax@kit.edu***	
Affiliation	Institute for Information Processing Technologies (ITIV); KIT	
Current Position	Head of Institute	
Vita	01.10.2014 Head of Institute: Institute for Information Processing Technologies (ITIV), KIT 01.12.2009 – 30.09.2014 Head of Electric/Electronic Engineering world wide at Daimler Busses 01.06.2005 – 31.05.2009 Director “Test-Engineering” at Mbtech Group 01.10.2002 – 31.05.2005 Head of Team “Component Testing” at Mbtech Group	
Fields of Interest	Systems Engineering, Life Cycles Models from V-Model to agile, Automotive Standards (ISO26262, Autosar, OSEK, CAN, …)-	
Memberships & Awards	01.10.2014 Director at Forschungszentrum Informatik for Electronic Systems and Microsystems Author of the Book:”Automatisiertes Testen Eingebetteter Systeme in der Automobilindustrie”	

Title/Name	Prof. Dr. Stefan Nickel	
Phone	+49 (0)721 608-43381	
E-Mail	***Stefan.Nickel@kit.edu***	
Affiliation	Institute of Operations Research: Discrete Optimization and Logistics, Karlsruhe Institute of Technology (KIT) Englerstr. 11, 76131 Karlsruhe, Germany	
Current Position	Head of the Chair: Discrete Optimization and Logistics at the IOR	
Vita	1995-1999 Assistant Professor, University of Kaiserslautern Since 1999 Associate Professor, University of Kaiserslautern 2003-2009 Chair in Operations Research and Logistics, University of Saarbrücken Since 2009 Chair in Discrete Optimization and Logistics, KIT	
Fields of Interest	▪ Modelling location decisions in Supply Chain Management ▪ Multiperiodic design and optimization of distribution networks ▪ Optimization methods in in-house logistics ▪ Optimization methods in health care	
Memberships & Awards	▪ INFORMS ▪ European Working Group on Locational Decisions (EWGLA) ▪ College on Locational Analysis (COLA) ▪ Gesellschaft für Operations-Research e.V. (GOR) ▪ Mathematical Programming Society (MPS)	

3 Study Plan (in accordance with SPO 2016)

3.1 Overall Program Objectives and Qualification Targets

All six executive master programs of the HECTOR School of KIT have the following qualification objectives in common:

1. Enabling the graduates to operate in an analytical and scientifically sound way
2. Enabling the graduates to independently apply and further develop methods and technologies in the areas of research and development
3. Enabling the graduates to perform successful, self-dependent, and innovative work which is related to their occupational fields in their respective areas of the specialization
4. Enabling the graduates to work on complex topics in the pursued specialization
5. Enabling the graduates to apply methods both in economic and in management-related issues
6. Enabling the graduates to assume leadership positions in the field of their chosen specialization, also in international contexts

3.2 Qualification Objectives for Mobility Systems Engineering and Management

The specific qualification objectives for the executive master program MSEM are the following:

1. The graduates are able to design, analyze and optimize electronic and mechatronic systems at the level of the latest technologies and tools, thereby taking into account the different stages of the life cycle of a system.
2. They have an overview of current methods and standardized models (e.g. waterfall model, scrum, V-Model), which comprise the development process of an electronic and especially an embedded electronic system (Cyber Physical System, CPS), and in applying them also include market-specific licensing and standardization aspects.
3. Graduates know various components of CPS such as actuators, sensors and processors and their different architectures. Moreover, they have an overview of the communication standards between the components.
4. They are able to independently drive system integration and to assess and evaluate a CPS under quality assurance aspects.
5. Graduates are also able to analyze and evaluate technological problems in the context of electronics development under economics aspects.
6. They are able to thoroughly understand the approach in the internal and external financial reporting and to apply it in the corporate context.
7. Furthermore, they are familiar with approaches to preparing and optimizing a company's strategic decisions.

8. They have mastered the essential skills of project management in an international context and, through their interdisciplinary training, can actively integrate those from various fields, hierarchical levels and cultural backgrounds and thus prepare and implement decisions concerning corporate strategy.
9. They are able to understand marketing, human resource management, and legal issues approaches in the technological context, to recognize and evaluate interconnections and thus, based on this, to evaluate the effectiveness of strategies. On the basis of this analysis, recommendations for action can be derived.

3.3 Program Structure and Curriculum

Excellence in Technology Management: Six Executive Master Programs are offered by the HECTOR School of Engineering and Management. The school – named after Dr. h.c. Hans-Werner Hector, the co-founder of the software company SAP – is run in cooperation with four University Departments. The programs are offered in

- Energy Engineering and Management (EEM)
- Financial Engineering (FE)
- Information Systems Engineering and Management (ISEM)
- Management of Product Development (MPD)
- Mobility Systems Engineering and Management (MSEM)
- Production and Operations Management (POM)

The concurrently taught Executive Master Program is designed for working professionals. Block lectures scheduled at intervals allow participants to continue with demanding careers while acquiring new skills. The lectures are scheduled to take place over a period of 15 months. Courses are divided into 10 intensive modules of 14 days each following a timetable of monthly intervals. Each participant will take the same sequence of courses throughout the program. The two-week block lectures allow a complete immersion into the academic environment without long interruption of existing work-related responsibilities. The program officially begins in October of each year and is completed with a Master Thesis.

The following table (**Fehler! Verweisquelle konnte nicht gefunden werden.**) shows the sequence of the modules in and the curriculum of the program.

Semester	Subject	Type of Module	Name of Module	Course	Credits
1	Management	MM1	Marketing and Information	1. Designing and Selling Solutions	6
				2. Information Systems Management	
				3. Big Data Methods	
				4. Legal Aspects of Information	
	Engineering	EM1	Processes, Methods and Tools of Systems Engineering	1. Fundamentals of Systems Engineering	6
				2. Modeling and Simulation	
				3. Process Models and Associated Assessments	
				4. Case Study in Embedded Systems Development (incl. Rapid Prototyping)	
				5. Big Data Management	
	Engineering	EM2	Systems Design	1. Control Systems Development	6
				2. Embedded Systems Computer Architecture	
				3. Electronic Systems Synthesis (Hardware and Software) incl. Case Study	
				4. Future Vehicle Concept Study	
	Management	MM2	Finance and Value	1. Management Accounting	6
				2. Financial Accounting	
				3. Strategic Financial Management	
				4. Case Studies	
2	Management	MM3	Decisions and Risk	1. Decision Modeling	6
				2. Risk Aware Decisions	
				3. Interactive Decisions	
				4. Robust and Stochastic Optimization	
	Engineering (elective)	EM3 ADAS	Functions of ADAS	1. Driver Assistance Systems	6
				2. Auto Control Systems	
				3. Driveability	
				4. Traffic Engineering and Control	
				5. Car-to-X-Communication	
	Engineering (elective)	EM3 E-Mobility	E-Mobility – Political and Technical Framework	1. Introduction into Requirements, Solutions and Challenges of E-Mobility	6
				2. Case Study	
				3. CO2-Balances: Well to Wheel	
				4. Transportation Markets and Policy	

Semester	Subject	Type of Module	Name of Module	Course	Credits
				5. Energy Distribution	
				6. Energy Management	
				7. Noise, Vibration and Harshness for E-Mobility	
	Engineering (elective)	EM4 ADAS	Components and Technology of ADAS	1. Automotive EMC Technology	6
				2. Automotive Lighting	
				3. Mobile Perception Systems	
				4. IT Safety and Security	
				5. Hands-on Training: Platooning	
	Engineering (elective)	EM4 E-Mobility	Components and Technology of E-Mobility	1. Electric Drive Trains	6
				2. Power Electronics	
				3. Energy Conversion	
				4. Energy Output	
				5. Energy Storage: H2-Storage	
				6. Energy Storage: Batteries and Fuel Cells, H2-Storage	
	Management	MM4	Innovation and Projects	1. Technology Driven Innovation	6
				2. International Intellectual Property Law	
				3. Project Management	
				4. Multi-Project Management in an International Setting	
3	Engineering	EM5	Systems Integration and Validation	1. Quality Assurance and Cost of QA of Electronic Systems	6
				2. Testing Automotive Systems (XiL, virtual testing,…)	
				3. Case Study in Testing Automotive Systems	
				4. Release-, Configuration- and Update-Management of self-learning Functionality	
	Management	MM5	Strategy and People	1. Strategic Management	6
				2. Managerial Economics	
				3. Business Organization and Corporate Law	
				4. Strategic Human Resource Management	
				5. Leadership and Conflict Management	
		Thesis	Master Thesis (maximum 9 months)		30

Tab. 3-1 Study Plan MSEM

3.4 Academic Calendar Intake 2020

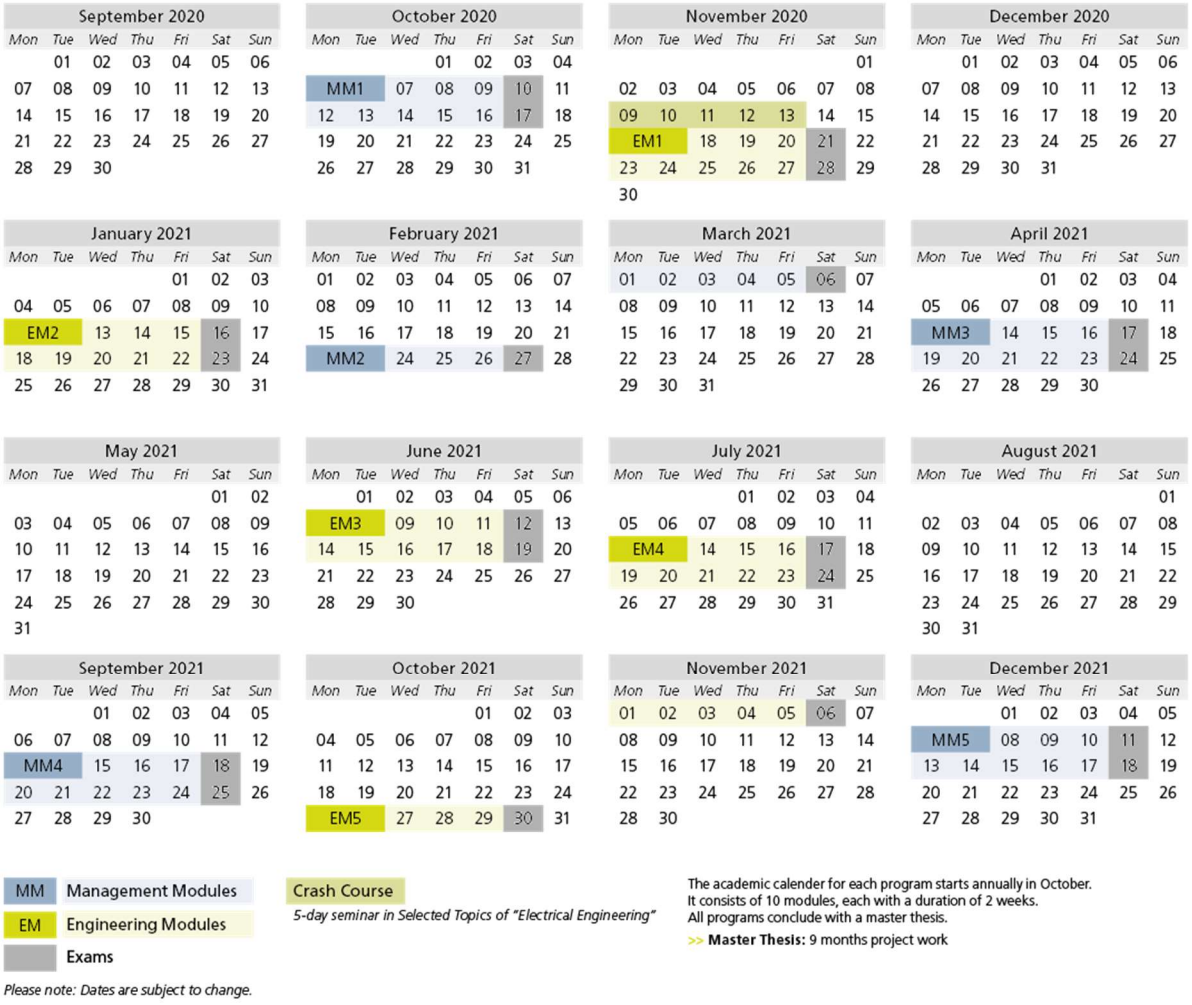

Figure 1: Academic Calendar Intake 2020 (the curriculum may be subject to change)

Selection of Elective Focus Area in Engineering Subject (SPO §19, par. 3)

There are two elective focus areas offered both within the subject of Engineering: Advanced Driver Assistance Systems (ADAS) and E-Mobility. The management modules and the engineering modules EM1, EM2 and EM5 are independent from the selection of the elective focus area and are identical for all students. The elective focus area ADAS comprises the modules EM3 “Functions of ADAS” and EM4 “Components and Technology of ADAS”, whereas the elective focus area E-Mobility contains the modules EM3 “Functions of E-Mobility” and EM4 “Components and Technology of E-Mobility”. A change between the elective focus area after EM3 is not possible. The students must select their elective focus area bindingly by January 25th, 2021. Therefore, the students submit the linked form to the HECTOR School Administration Office.

3.5 Teaching Structure

HECTOR School's programs are more than typical MBA programs. The primary goal is to enable young professionals to take a holistic approach when managing highly interdependent processes. Leadership for engineers in today's fast changing and complex environment does imply technological and organizational responsibilities and requires economical accountability and human resource management know-how. Therefore, all programs are based on 5 Management Modules where the participants are provided with general knowledge in Finance, Accounting, Marketing, Multi-Project Management and International Law so they can consider commercial consequences of business decisions.

The engineering emphasis of each Master Program is laid on 5 Engineering Modules adapted to each specialization. The lectures in the Masters-specific field provide insight into the newest research topics. They convey current and state-of-the-art methodology necessary to master the scope of innovative technologies. These engineering lectures also comprise the theoretical background necessary to model and analyze key decision problems in manufacturing sites.

Workshops and case studies allow ample opportunity to explore the direct applications of the modules simulating the real business environment. The programs conclude with a Master thesis which allows the participants to work on a research project reflecting their own company's needs and its specific business environment. The final title bestowed after having successfully completed the programs is the Master of Science (M.Sc.) of the Karlsruhe Institute of Technology (KIT).

3.6 Examination Structure

3.6.1 General Information

Examinations take place on both Saturdays during the module. Examinations can be written, oral or controls of success of another kind (e.g. a documentation of a case study). You may find the detailed information about the examination type in each lecture description. The examinations usually take place in rooms at the International Department. The exact location and dates will be communicated at the beginning of the module. Attendance in lecture is mandatory, strong participation is highly recommended. If students are unable to participate in the exam an official excuse (written) must be issued, prior to exam start.

3.6.2 Examination Process

Each student must show his identification card at exam start. The results of the exams are announced right after the examination if it is an oral exam and about four to six weeks after the examination if it is a written exam. The exam results can be find after each module on a transcript, which will be uploaded into a personal folder on HECTOR School SharePoint.

3.6.3 Exam Review

An exam review will be provided at the first Monday of the next module, where students may get an insight into the exams and have the opportunity to ask questions. There is no possibility to contest the exam if not attended the exam review. Participants need to bring their Student ID to the exam review. For further information, please see the General Study and Examination Regulations (see 8.4).

3.7 Lecturers

3.7.1 Management Modules

Name	Institute
Program Director	
Prof. Dr. Stefan Nickel	Institute for Operations Research, KIT
Module Supervisors:	
Prof. Dr. Martin Klarmann	Institute of Information Systems and Marketing, KIT
Prof. Dr. Stefan Nickel	Institute for Operations Research, KIT
Prof. Dr. Petra Nieken	Institute of Management, KIT
Prof. Dr. Martin E. Ruckes	Institute for Finance, Banking and Insurance, KIT
Prof. Dr. Orestis Terzidis	Institute for Entrepreneurship, Technology Management and Innovation, KIT
Lecturers in Alphabetical Order	
Dr. Abilio Avila	Institute of Entrepreneurship, Technology Management and Innovation, KIT
Prof. Dr. Kerstin Fehre	Vlerick Business School
Prof. Dr. Oliver Grothe	Institute for Operations Research, KIT
Dr.-Ing. Iris Heckmann	FZI Forschungszentrum Informatik
Sven Jacobs	Norton Rose Fulbright LLP
Prof. Dr. Anja Kern	Cooperative State University, DHBW Mosbach
Dr.-Ing. Tobias Kunkel	Institute of Human and Industrial Engineering (ifab), KIT
Dr.-Ing. Robert Landwehr	Daimler AG
Prof. Dr. Stefan Morana	Universität des Saarlandes
Gerald Oerter	Focus Sales, Consulting Gerald Oerter
Prof. Dr. Clemens Puppe	Institute of Economics, KIT
Prof. Dr. Steffen Rebennack	Institute of Operations Research, KIT
Prof. Dr. Martin Schulz	German Graduate School of Management and Law
Dr. Marcel Sinske	Institute of Operations Research, KIT
Prof. Dr. Indra Spiecker gen. Döhmann	Department of Law, Goethe Universität Frankfurt am Main
Dr. Jan-Oliver Strych	Institute for Finance, Banking and Insurance, KIT

3.7.2 Engineering Modules

Name	Institute
Program Directors	
Prof. Dr.-Ing. Eric Sax	Institute for Information Processing Technologies (ITIV), KIT
Module Supervisors	
Prof. Dr.-Ing. Eric Sax	Institute for Technic of Information Processing (ITIV); KIT
Prof. Dr.-Ing. Martin Doppelbauer	Institute of Electrotechnical Engineering, KIT
Prof. Dr. rer. nat. Frank Gauterin	Institute of Vehicle Technology, KIT
Lecturers in Alphabetical Order	
Daniel Baumann	Institute for Technic of Information Processing (ITIV); KIT
Prof. Dr.-Ing. Dr. h. c. Jürgen Becker	Institute for Information Processing Technologies (ITIV), KIT
Frank Blucha	Harmann Becker Automotive Systems
Prof. Dr.-Ing. Rüdiger Dillmann	Institute of Anthropomatics, KIT
Prof. Dr. Helmut Ehrenberg	Institute for Applied Materials – Energy Storage Systems, KIT
Prof. Dr. Maximilian Fichtner	Institute of Nanotechnology, KIT
Dr.-Ing. Michael Frey	Institute of Vehicle Technology, KIT
Dr.-Ing. Martin Gießler	Institute of Vehicle Technology, KIT
Prof. Dr. Martin Heine	Hochschule Furtwangen
Prof. Dr.-Ing. Marc Hiller	Elektrotechnisches Institut (ETI), KIT
Dr. Frank Hofmann	Robert Bosch GmbH
Prof. Dr.-Ing. Sören Hohmann	Institut für Regelungs- und Steuerungssysteme, KIT
PD Dr. rer. pol. Patrick Jochem	Institute for Industrial Production (IIP), KIT
Prof. Dr. Kay Mitusch	Institute for Economic Policy Research, KIT
Dr. Christian Müller	MBtech Group GmbH & Co. KG
Prof. Dr. Jörn Müller-Quade	Institute for Cryptography and Security, KIT
Prof. Dr. Cornelius Neumann	Light Technology Institute, KIT
Dipl.-Ing. Sascha Ott	Institute of Product Development, KIT
Dr. Stefan Pfahl	Daimler AG
Dr. Uwe Reinhardt	IAV GmbH
Dr.-Ing. Oliver Sander	Institute for Technic of Information Processing (ITIV); KIT
Prof. Dr.-Ing. Christoph Stiller	Institut für Mess- und Regelungstechnik, KIT
Prof. Dr. York Sure-Vetter	Institute of Applied Informatics and Formal Description Methods, KIT
Prof. Dr.-Ing. Peter Vortisch	Institute for Transport Studies, KIT

Name	Institute
Dr. Frieder Scheiba	Institute for Applied Materials- Energy Storage Systems
Prof. Dr. Hartmut Schmeck	Institute of Applied Informatics and Formal Description Methods, KIT
Dipl.-Ing. Hans-Joachim Unrau	Institute for Piston Engines, KIT

4 Description of the Management Modules

4.1 Marketing and Information

Module Name			
Marketing and Information			
Semester	Subject	Module Supervisor	Credit Points for Module
1	Management	Prof. Dr. Martin Klarmann	6
Module Content			
Information becomes more and more important as a source of value creation for companies. This module looks at how information can be used to improve business performance in today's business environment. In the first week, the module looks at information-related topics in general, covering issues such as the implementation of information systems, the analysis of (big) data, and legal requirements surrounding the use of (customer) data in firms. In the second week, the module covers how to design and sell customer solutions. These hybrid offerings of products and services require careful analyses of customer information to work.			
Learning Results (LR)			
LR-1: Participants will know how to set up effective information systems LR-2: Participants will know how key issues surrounding the analysis of (big) data and machine learning LR-3: Participants will know the boundaries to the use of information and data set by the legal environment LR-4: Participants will know how to create value from information using customer solutions LR-5: Participants will know how to empirically test hypotheses about sources of value creation using conjoint analysis			
Workload			
Total 180h, hereof 75h contact hours, 105h homework and self-studies (hereof 65 during module, 40 in preparation of module)			

Controls of Success In MM 1 (4.1)	Modality of Examination	Performance and Duration of Examination	Prerequisites for Exam-participation	Examination Period	Graded
4.1.1 Designing and Selling Solutions	Examination of another kind	Presentation of Case Study in, approx. 15 minutes per candidate	None	During course	Yes
4.1.2 Information Systems Management	Examination of another kind	Presentation of Case Study in, approx. 15 minutes per candidate	None	During course	Yes
4.1.3 Big Data Methods	Study Achievement	None	None	-	No
4.1.4 Legal Aspects	Study	None	None	-	No

of Information	Achievement				
Grading: The module grade shall be considered proportionally to the credits assigned to the courses.					

4.1.1 Designing and Selling Solutions

Course Name			
Designing and Selling Solutions			
Semester	Module Type	Allocated to the following Module	Lecturers
1	Compulsory (course is assigned to student by examination board)	Marketing and Information	Prof. Dr. Martin Klarmann Dr. Sven Feurer Gerald Oerter
Recurrence	Mode of Teaching	Workload	Credit Points for Course
Each winter semester	Lecture	Total 90h, hereof 37,5h contact hours, 52,5h homework and self-studies	3
Overall Course Objectives			
The course seeks to familiarize participants with the necessary techniques to design and sell solutions (i.e., hybrid offerings of services and products) that provide extra value to customers. These techniques are especially suited for markets where low-cost competitors from emerging markets offer products that are comparable in their performance to those of European manufacturers			
Learning Targets			
Participants: ▪ are able to develop customer value propositions for new offerings ▪ can set value-based prices ▪ can test hypotheses about what creates customer value using conjoint analysis ▪ are able to program simple online questionnaires ▪ are able to use Python to create experimental designs, analyze regression models, and produce simple visuals ▪ are prepared for price negotiations in B2B markets ▪ know the basic elements of customer-centric strategies			
Course Content			
▪ Value Creation (Monday) ▪ Solution Design (Tuesday) ▪ Value Appropriation (Wednesday) ▪ Negotiation for Value (Thursday) ▪ Customer Centricity (Friday)			
Literature			
Anderson, J., Kumar, N., & Narus, J. A. (2007). Value merchants: Demonstrating and documenting superior value in business			

markets.

Fader, P. (2012). Customer centricity: Focus on the right customers for strategic advantage. Wharton digital press.

Homburg, C., Schäfer, H., & Schneider, J. (2012). Sales excellence: Systematic sales management. Springer Science & Business Media.

Osterwalder, A., Pigneur, Y., Bernarda, G., & Smith, A. (2015). Value proposition design. Wiley.

Prerequisites for participation in course

No prerequisites.

Modality of Exam

See 4.1

4.1.2 Information System Management

Course Name

Information Systems Management

Semester	Module Type	Allocated to the following Module	Lecturers
1	Compulsory (course is assigned to student by examination board)	Marketing and Information	Prof. Dr. Stefan Morana
Recurrence	**Mode of Teaching**	**Workload**	**Credit Points for Course**
Each winter semester	Lectures and exercises	Total 36h, hereof 15h contact hours, 21h homework and self-studies	1,2

Overall Course Objectives

The primary objective of the course is to enable participants to understand the importance of the resource information in business and society as well as to manage information system from a socio-technical perspective. Thereby, participants of the course will be able to play a vital role at the intersection of technical and business issues, being able to bridge the gap between company's customers and end users, Line-of-Business experts and IT experts.

Learning Targets

Participants:

- understand the need for managing the resource information
- understand key concepts and implications of information systems (IS)
- get an overview on the different phases of the IS lifecycle
- know methods and techniques in order to successfully create value with IS.

Course Content

The course will cover the following topics ▪ Management of the resource information in organizations ▪ Introduction into the concept of IS from a socio-technical perspective ▪ Importance and special characteristics of the IS life cycle ▪ Methods and techniques for executing the pre-implementation, implementation, and post-implementation phases The lectures will be accompanied by hands-on exercises that will be used to review the presented material and enhance understanding.
Literature
Relevant literature will be distributed with the course materials.
Prerequisites for participation in course
No prerequisites required.
Modality of Exam
See 4.1

4.1.3 Big Data Methods

Course Name			
Big Data Methods			
Semester	Module Type	Allocated to the following Module	Lecturer
1	Compulsory (course is assigned to student by examination board)	Marketing and Information	Prof. Dr. Oliver Grothe
Recurrence	Mode of Teaching	Workload	Credit Points for Course
Each winter semester	Lecture	Total 28,8h, hereof 12h contact hours, 16,8h homework and self-studies	0,96
Overall Course Objectives			
The primary objective of the course is to enable participants to understand the importance of limited information content in real data and implications for how precise we can learn from data. Furthermore, the students learn how to apply linear and slightly non-linear regression techniques using Python and also apply classification techniques.			
Learning Targets			
Participants: ▪ know what Big Data stands for. ▪ understand basic statistical concepts of statistical learning. ▪ have a first profound understanding of regression and classification techniques.			

▪ know and apply methods for the validation of results from data.
Course Content
The course will cover the following topics ▪ statistical inference ▪ statistical learning ▪ introduction to regression and classification techniques ▪ introduction to evaluation techniques The lectures will be completed by hands-on programming and data analysis exercises in Python that will be used to review the presented material and enhance understanding.
Literature
Relevant literature will be distributed with the course materials.
Prerequisites for participation in course
No prerequisites required.
Modality of Exam
See 4.1

4.1.4 Legal Aspects of Information

Course Name			
Legal Aspects of Information			
Semester	Module Type	Allocated to the following Module	Lecturer
1	Compulsory (course is assigned to student by examination board)	Marketing and Information	Prof. Dr. Indra Spiecker gen. Döhmann
Recurrence	Mode of Teaching	Workload	Credit Points for Course
Each winter semester	Lecture	Total 25,5h, hereof 10,5h contact hours, 14,7h homework and self-studies	0,84
Overall Course Objectives			
The fundamental knowledge of the law governing the distribution of information supports participants in the adaptation of business strategies in today's digitalized business world. The participants will be enabled to identify and solve relevant problems from the areas of data and privacy protection in relation to business activities.			
Learning Targets			

Participants

- Know relevant legal argumentation skills and the general structure of laws
- Know relevant principles and argumentations in data protection law, also in comparison with U.S. law
- Understand the difference between EU and national law and its implications for data protection law
- Are able to identify relevant legal problems in data protection law and solve small cases.
- Find and discuss different legal solutions on the basis of general legal argumentation skills to data protection law problems

Course Content

Managers and project leaders involved in the development, installment and management of digitalized products and services need a basic knowledge of data protection law in order to avoid costly decisions. This is even more important as the new EU-wide data protection regulation (GDPR) provides for heavy sanctions against privacy violators enforced by independent agencies and data subjects alike.

The lecture deals with the basics of data protection law as structured within the EU: What are relevant data protection regulations? In what respect is (EU) law influencing the national regulatory systems? What are the core issues regulated within the EU-General Data Protection Regulation? What do businesses dealing in digitalized worlds have to be aware of? The lecture aims at a general understanding of the mechanisms of European data protection law with some excursions into U.S. law. Students will learn what to pay attention to when personal data is involved in business transactions. This knowledge, however, can only be rightly understood and applied, if students are aware of the general legal argumentation structures. Therefore, these will be dealt with, also.

Literature

- Simitis/Hornung/Spiecker gen. Döhmann (Eds.), Kommentar Datenschutzrecht, 2019
- Tinnefeld/Buchner/Petri, Einführung in das Datenschutzrecht, 2017

Prerequisites for participation in course

Basic knowledge/practical experience in European Law as well as data protection law would be helpful but is not required

Modality of Exam

See 4.1

4.2 Finance and Value

Module Name			
Finance and Value			
Semester	Subject	Module Supervisor	Credit Points for Module
1	Management	Prof. Dr. Martin E. Ruckes	6

Module Content

The module “Finance and Value” consists of three courses related to the creating of value in business environments: Management Accounting, Financial Accounting, and Strategic Financial Management. Applying the acquired knowledge in case studies round out the module.

The module shows how value is created in businesses by the careful quantitative assessment of the business environment and the identification of valuable opportunities, a thoughtful system of implementing business opportunities that coordinates activities by providing clear metrics for value creation, and the thorough understanding about how business decision translate into financial statements, often the firm’s most important channel of communication to outside stakeholders.

Using the knowledge acquired in the courses in case studies reveals how to apply important business concepts to real world situations.

Learning Results (LR)

Participants

- are able to analyze business environments and to identify and finance value creating business opportunities,
- are in a position to implement business opportunities by designing an internal accounting system that coordinates the firm’s business activities,
- understand how business decisions are communicated to outside stakeholders via a system of financial statements.

Workload

Total 180h, hereof 75h contact hours, 105h homework and self-studies (hereof 65 during module, 40 in preparation of module)

Controls of Success In MM 2 (4.2)	Modality of Examination	Performance and Duration of Examination	Prerequisites for exam-participation	Examination Period	Graded
4.2.1 Management Accounting	Written examination	120 minutes	None	At the end of the module	Yes
4.2.2 Financial Accounting					
4.2.3 Strategic Financial Management					
4.2.4 Case Studies	Examination of another kind	Presentation of Case Study, Approx. 15 minutes per candidate	Written draft and Presentation	During course	Yes

			of Case Study		
Grading: The module grade shall be considered proportionally to the credits assigned to the courses.					

4.2.1 Management Accounting

Course Name			
Management Accounting			
Semester	Module Type	Allocated to the following Module	Lecturer
1	Compulsory (course is assigned to student by examination board)	Finance and Value	Prof. Dr. Anja Kern
Recurrence	Mode of Teaching	Workload	Credit Points for Course
Each winter semester	Lecture and exercises	Total 54h, hereof 22,5h contact hours, 31,5h homework and self-studies	1,8

Overall Course Objectives

Participants get an overview of accounting and controlling topics. They understand specific accounting and controlling topics, they are able to apply these to assignments and they are able to position these in the context of their own work.

Learning Targets

Participants gain an understanding of key concepts and techniques of management accounting, are able to use relevant costs for decision making, and are in the position to purposeful apply instruments for planning and control.

Course Content

Participants will learn about:

- Product costing concepts
- Cost allocation: between departments and from activities to products
- Job costing
- Process costing
- Short-term decision making, cost-volume-profit analysis
- Strategic investment decisions
- Budgeting and variance analysis
- Responsibility accounting
- Performance management

Literature

Cost Management by M. Wouters, F. Selto, R. Hilton, and M. Maher, 2012, McGraw-Hill Higher Education, ISBN-13 9780077132392

Prerequisites for participation in course

Knowledge about principles of financial accounting as well as discounting of future cash flows is desirable, but not obligatory required.
Modality of Exam
See 4.2

4.2.2 Financial Accounting

Course Name			
Financial Accounting			
Semester	Module Type	Allocated to the following Module	Lecturer
1	Compulsory (course is assigned to student by examination board)	Finance and Value	Dr. Jan-Oliver Strych
Recurrence	Mode of Teaching	Workload	Credit Points for Course
Each winter semester	Lecture and exercises	Total 54h, hereof 22,5h contact hours, 31,5h homework and self-studies	1,8

Overall Course Objectives
The course objective is to understand and critically assess financial statements. Participants know about the main principles and concepts of financial accounting used to prepare the balance sheet and income statement. Financial statements are analyzed to reveal profitability, identify cash flows and track the operating cycle.
Learning Targets
Participants are able to ▪ understand the balance sheet, income statement and statement of cash flow. ▪ track corporate decision-making into financial statements. ▪ apply financial statement analysis.
Course Content
This course provides participants with an understanding of the key financial statements and its underlying accounting principles. It is shown how investment and financing decisions affect the balance sheet and the income statement. Financial statement analysis is applied to measure a firm's liquidity, operational efficiency, and profitability.
Literature
Penman, S.H. (2013): Financial Statement Analysis and Security Valuation, 5th ed., McGraw Hill. Hawawini, G. and Viallet, C. (2011): Finance for Executives, 4th ed., South-Western Publishing.
Prerequisites for participation in course

No prerequisites.
Modality of Exam
See 4.2

4.2.3 Strategic Financial Management

Course Name			
Strategic Financial Management			
Semester	Module Type	Allocated to the following Module	Lecturer
1	Compulsory (course is assigned to student by examination board)	Finance and Value	Prof. Dr. Martin E. Ruckes
Recurrence	Mode of Teaching	Workload	Credit Points for Course
Each winter semester	Lecture and exercises	Total 54h, hereof 22,5h contact hours, 31,5h homework and self-studies	1,8

Overall Course Objectives
The course objective is to understand the main principles of finance and thereby be able to analyze corporate investment and financing decisions, such as ▪ valuation of risky cash flows and its application to corporate investments, ▪ financing choices and firm valuation.
Learning Targets
Participants ▪ are placed in a position to judge corporate investment projects from a financial point of view. ▪ gain a thorough comprehension of the main principles of business finance. ▪ are able to assess the value of business enterprises.
Course Content
This course begins with an overview of the environment in which financial decisions occur and of the financial information available. Investment rules, such as the net present value rule are applied to value securities and to capital budgeting. It follows the valuation of risky cash flow streams resulting from corporate projects or entire firms. After discussing the instruments of long-term financing, the decision to payout capital are addressed.
Literature
Hawawini, G. and Viallet, C. (2015): Finance for Executives, 5th ed., South-Western Publishing
Prerequisites for participation in course
No prerequsites required.

Modality of Exam
See 4.2

4.2.4 Case Studies

Course Name			
Case Studies			
Semester	Module Type	Allocated to the following Module	Lecturers
1	Compulsory (course is assigned to student by examination board)	Finance and Value	Prof. Dr. Martin E. Ruckes Dr. Jan-Oliver Strych
Recurrence	Mode of Teaching	Workload	Credit Points for Course
Each winter semester	Group Projects	Total 18h, hereof 7,5h contact hours, 10,5h homework and self-studies	0,6

Overall Course Objectives

Practice the valuation of a firm by applying concepts and methods from finance and accounting.

Learning Targets

Participants:

- perform business analysis to identify the firm's profit drivers and key risks,
- use financial data and other information to evaluate the current and past performance of the firm
- forecast a firm's future in terms of cash flows and/or earnings to practice a firm valuation under a pessimistic or optimistic view.

Course Content

- The case study centers around the valuation of a company and its equity using publicly available information.
- It is a group project where group assignments are available at the sharepoint.
- Each group makes a case for buying or selling the company's stock. This is done by performing a firm valuation and presenting it in class.

Literature

- Recent annual report of ase companies
- Presentation of case companies

Prerequisites for participation in course

- Participation in the course *Financial Accounting* and *Strategic Financial Management* is mandatory.
- Knowledge from both courses is necessary to perform the case study.

Modality of Exam
See 4.2

4.3 Decisions and Risk

Module Name			
Decisions and Risk			
Semester	Subject	Module Supervisor	Credit Points for Module
2	Management	Prof. Dr. Stefan Nickel	6

Module Content

The module has the goal to make the students familiar with different facets of quantitative decision making comprising general model building, risk assessment, random effects, and multiple agents.

The module is divided into four courses: “Decision Modeling” serves as an elementary class (including software lab applications) targeting the development of basic quantitative modeling knowledge. Building upon this course, “Robust and Stochastic Optimization” and “Risk Aware Decisions” then focus on bridging the gap to reality by introducing different types of uncertainty and risk-awareness considerations into the models. Finally, “Interactive Decisions” analyzes from a game-theoretic point of view how decisions are made in the presence of multiple decision makers each focusing on individual interests.

Learning Results (LR)

Participants

- know and explain basic modelling techniques for quantitative decision making
- are capable of extending decision models to real world conditions involving different uncertainty representations (e.g., risk concepts, stochasticity) as well as practice-oriented features (e.g., industrial applications)
- apply decision support software systems to solve quantitative decision and optimization problems
- know and estimate game-theoretic effects in interactive decision making processes

Workload

Total 180h, hereof 75h contact hours, 105h homework and self-studies (hereof 65 during module, 40 in preparation of module)

Controls of Success In MM 3 (4.3)	Modality of Examination	Performance and Duration of Examination	Prerequisites for exam-participation	Examination Period	Graded
4.3.1 Decision Modeling	Written examination	120 minutes	None	At the end of the module	Yes
4.3.2 Risk Aware Decision					
4.3.3 Interactive Decisions					
4.3.4 Robust and Stochastic Optimization					
Grading: The module grade shall be considered proportionally to the credits assigned to the courses.					

4.3.1 Decision Modeling

Course Name			
Decision Modeling (+Computer Tutorials)			
Semester	Module Type	Allocated to the following Module	Lecturer
2	Compulsory (course is assigned to student by examination board)	Decisions and Risk	Prof. Dr. Stefan Nickel
Recurrence	Mode of Teaching	Workload	Credit Points for Course
Each summer semester	Lectures and exercises	Total 54h, hereof 22,5h contact hours, 31,5h homework and self-studies	1,8

Overall Course Objectives

The course has the goal to make the students familiar with theoretical and practical modelling techniques used for supporting quantitative decision making. Students gain knowledge in modeling systems behavior in specific industrial applications. Moreover, the usage of computers in practical applications of quantitative decision-making problems is highlighted in the software laboratory. An important benefit lies in the ability to assess and estimate general possibilities and fields of usage of decision support software for solving decision/optimization tasks in practice.

Learning Targets

Participants

- know and explain basic modelling techniques for quantitative decision making
- are able to formalize decision and optimization problems using decision support models
- are capable of extending decision models to real world conditions in order to achieve advanced models for industrial applications
- apply decision support software systems to solve quantitative decision and optimization problems
- know the limits of computer-supported problem solving based on complexity considerations

Course Content

Many real-life problems can be described and solved by decision support models. The course "Decision Modelling" tackles the modelling of decision and optimization problems by means of formal modelling methods and illustrates how these techniques can be utilized to solve real-world problems in business and industry applications. To this end, the course gives a concise discussion of modelling possibilities for quantitative decision making where the general goal is to design and operate a system under scarce resources.

With respect to a wide range of application possibilities, different modelling concepts are introduced with different focuses: mathematical programming as a general method for modelling and solving problems from different domains, queueing systems for analysing waiting times and lines in queueing networks, multi-criteria concepts as possibilities to integrate multiple stakeholders into the decision making process, and scheduling as a special example of application-driven modelling.

Additionally, the course consists of a software laboratory part where students get on hands with state-of-the-art IT tools for mathematical modelling, optimization, simulation, and decision support. Fundamental problems from supply chain management, logistics, and health care are first introduced and modelled theoretically; afterwards these models are solved for exemplary data settings with computer software. As a result of the complexity of real-world settings, a final focus of the course

is put on practical issues and limits of the presented modelling approaches as well as on a research outlook.
Literature
▪ Reid, Sanders: Operations Management - An integrated approach, Wiley, 2007 ▪ Chase, Aquilano, Jacobs: Production and Operations Management: Manufacturing and Services, 8th edition, McGraw-Hill, 1998 ▪ Vercellis: Business Intelligence - Data Mining and Optimization for Decision Making, Wiley, 2009 ▪ Barbosa-Póvoa, Corominas, Miranda: Optimization and Decision Support Systems for Supply Chains, Springer, 2017 ▪ Pinedo: Scheduling – Theory, Algorithms, and Systems, 2nd edition, Springer, 2012 ▪ Stidham: Optimal Design of Queueing Systems, CRC Press, 2009 ▪ Ehrgott: Multicriteria Optimization, Springer, 2000 ▪ Sarker, Newton: Optimization Modelling - A practical approach CRC Press, 2008
Prerequisites for participation in course
Firm knowledge of the basics of mathematics and statistics as taught in Bachelor and Master university programs is expected.
Modality of Exam
See 4.3

4.3.2 Risk Aware Decisions

Course Name			
Risk Aware Decisions (+Case Studies + Finance)			
Semester	Module Type	Allocated to the following Module	Lecturer
2	Compulsory (course is assigned to student by examination board)	Decisions and Risk	Dr.-Ing. Iris Heckmann
Recurrence	Mode of Teaching	Workload	Credit Points for Course
Each summer semester	Lectures, exercises and case study	Total 36h, hereof 15h contact hours, 21h homework and self-studies	1,2
Overall Course Objectives			
Each process and decision in business is prone to uncertainty. Wrong assessments and misjudgments may lead to unforeseen developments, which may have important consequences when detected (too) late. Accordingly, uncertainty needs to be continuously monitored and managed. Along with an increasing number of relevant uncertainties, the importance given to risk considerations has grown significantly in the recent decades. As a result, we have observed this term being applied to many different areas. Particularly, in supply chain management, researchers have felt the need to somehow capture risk in optimization models built for supporting the decision-making processes. Due to the increasing complexity and interrelation of modern networks, the type and nature of uncertain developments together with the impact of an action have become hard or			

even impossible to predict. Additionally, major disruptions like the 2011 flooding in Thailand, the eruption of the Icelandic volcano, or labor strikes, revealed a lack of preparedness of managers towards uncertain developments in general.

The main goal of this course is to make the students familiar with the challenges related to the decision-making process under risk as well as to available decision-support models.

Learning Targets

According to the overall course objectives, participants' learning targets include the following aspects:

- Knowledge of real case situations and cascading conditions that are referred to as "risk"
- Understanding of the concept risk as it is used in different application domains
- Knowledge of different quantification metrics – their definition as well as advantages and disadvantages of their application
- Knowledge of basic risk-aware modelling principles used to formulate decision-support models

Course Content

The course is divided into two parts. During the first part the students are provided with a bundle of real cases that demonstrates how disruptive events can result in major disruptions all referred to as risk. By the means of these real case situations, we explain the diversity of cascading effects that evolve over time and over networks. Corresponding, we define concepts strongly related to the concept of risk, define the concept risk itself and offer first modelling principles that have the ability to capture risk. At the end of the first part, the students have a broad understanding of risk and accompanying concepts.

In the second part of the course, we introduce existing decision-support models and discuss their usefulness with respect to their level of risk-awareness. Models are introduced with different application focus, e.g. facility location and allocation models, inventory models, network flow models, and with varying underlying methodology, e.g. stochastic programs, robust and chance-constrained models.

Literature

- Bernstein, P.L. (1998). Against the Gods: The remarkable Story of Risk. New York: John Wiley.
- Breakwell, G.M. (2007). The psychology of risk. Cambridge: Cambridge University Press.
- Chopra, S. and P. Meindl (2004). Supply Chain Management. New York: Pearson Education Inc.
- Ericson, C.A. (2005). Hazard Analysis Techniques for System Safety. Hoboken, NJ: John Wiley & Sons, Inc.
- Sheffi, Y. (2005). The resilient enterprise: Overcoming Vulnerability for Competitive advantages, Vol 1 of MIT Press Books. Cambridge: MIT Press.
- Simchi-Levi, D. (2010). Operations rules. Cambridge: MIT Press.

Prerequisites for participation in course

Firm knowledge of the basics of mathematics and statistics as taught in Bachelor and Master university programs is expected.

Modality of Exam

See 4.3

4.3.3 Interactive Decisions

Course Name			
Interactive Decisions			
Semester	Module Type	Allocated to the following Module	Lecturer
2	Compulsory (course is assigned to student by examination board)	Decisions and Risk	Prof. Dr. Clemens Puppe
Recurrence	Mode of Teaching	Workload	Credit Points for Course
Each summer semester	Lectures and exercises	Total 54h, hereof 22,5h contact hours, 31,5h homework and self-studies	1,8

Overall Course Objectives

The objective of the course is to provide a rigorous introduction to game theory and its many applications in economics and the management sciences. The participants should also be made aware of the limitations of the classical approaches to the modelling of strategic interaction and be introduced to recent developments in behavioral economics.

Learning Targets

Participants understand the fundamental concepts and formal results of game theory in a mathematically rigorous way. The participants are able to infer the behavioral implications of game theory and can apply basic game theoretic models and concepts in real life contexts.

Course Content

Dominated and dominant strategies, Nash equilibrium, Prisoners' dilemma, Dynamic games and game trees, Subgame-perfect equilibrium, Games of incomplete information, Expected utility theory, Bayesian Nash equilibrium, Auction theory, Experimental game theory, Ultimatum and dictator games, Behavioral economics, Level-k thinking.

Literature

- R. Gibbons, A Primer in Game Theory, 1992.
- D. Kreps, Notes on the Theory of Choice, 1988.
- R. Pindyck & D. Rubinfeld, Microeconomics, 9th Edition, 2018.

Prerequisites for participation in course

No formal prerequisites, but basic knoweldge of proabability theory and calculus will be helpful.

Modality of Exam

See 4.3

4.3.4 Robust and Stochastic Optimization

Course Name			
Robust and Stochastic Optimization			
Semester	Module Type	Allocated to the following Module	Lecturers
2	Compulsory (course is assigned to student by examination board)	Decisions and Risk	Prof. Dr. Steffen Rebennack Dr. Marcel Sinske
Recurrence	Mode of Teaching	Workload	Credit Points for Course
Each summer semester	Lectures and exercises	Total 36h, hereof 15h contact hours, 21h homework and self-studies	1,2

Overall Course Objectives

The course provides an up-to-date treatment of important aspects of optimization under uncertainty by applying techniques from robust and stochastic optimization. There are some connections with almost all other courses.

Learning Targets

Participants

- learn to understand how uncertainty can effect decisions in optimization problems
- become able to decide when uncertainty should be modeled in optimization problems
- gain knowledge in modeling uncertainties with robust and stochastic optimization techniques
- understand the advantages and disadvantages of robust and stochastic optimization
- are able to interpret solutions obtained by robust or stochastic optimization problems

Course Content

Uncertain decision problems, robust optimization, interval uncertainty, polyhedral uncertainty, stochastic optimization, deterministic equivalent, extensive form, scenario-trees, scenario generation, value-of-the-stochastic-solution, multi-stage problem formulation, chance-constraints, stochastic dynamic programming.

Literature

- “Robust Optimization”, by Aharon Ben-Tal, Laurent El Ghaoui and Arkadi Nemirovski, Princeton Series in Applied Mathematics, 2009
- “Introduction to Stochastic Programming”, by John R. Birge and François Louveaux, Springer Series in Operations Research and Financial Engineering, 2nd ed. 2011

Prerequisites for participation in course

Basic knowledge about Operations Research and basic familiarity with elementary probability theory and statistics.

Modality of Exam

See 4.3

4.4 Innovation and Projects

Module Name			
Innovation and Projects			
Semester	Subject	Module Supervisor	Credit Points for Module
2	Management	Prof. Dr. Orestis Terzidis	6

Module Content

Technology represents a crucial source for new ventures and belongs to the most important drivers of competitive success. However, technology ventures have their own characteristics and require specific skills and techniques. The main objective of this module is to generate a deep understanding of technology venturing and the specific management approaches that address the characteristics of technology-driven innovation. The participants will learn specific techniques and methods to manage a technology venture.

For this purpose, this module consists of the two building blocks: Technology-driven innovation and project management.

Through the technology-driven innovation part of the module, participants will experience how to implement a technology-driven innovation approach and learn how to develop a successful product and a solid business model based on a new or existing technology. This includes the assessment of the technological strengths and limitations, the development of value profiles for technology applications, and a process for the selection of suitable applications and appropriate business models. Furthermore, this module addresses the fundamental key elements necessary to understand the challenges involved with intellectual property (IP) protection and elaborates a general understanding of the mechanisms of national and international IP law.

The second part of the module addresses the fact that the environment in which companies are operating has accelerated noticeably and is characterized by a high rate of market and technological changes. The technology, market, and competitive environment are developing continuously. As a result, companies are under constant pressure to adapt quickly to changing circumstances and offer a clear benefit to their customers and stakeholders. The vehicle to adapt the organization, address the stakeholder needs and implement a chosen strategy is the management of successful innovation projects. Therefore, entrepreneurial organizations need to manage and implement projects in highly dynamic business environments. The successful implementation of projects under such uncertain circumstances demands the use of methods that welcome changes and balance discipline and agility. Particularly in fast-paced international markets and markets with intensive competition, the use of highly adaptive methods is vital for the success of projects and the company. Through the project management training, the participants will gain a sound understanding of traditional and adaptive project management methods and learn how to implement successful projects. The participants will become familiar with a set of actionable tools to initiate, plan and manage projects, taught in interactive lectures and by working in groups.

Learning Results (LR)

LR-1: Develop a deep understanding of technology driven innovation and the management approaches necessary to succeed.

LR-2: Gain an overview of the fundamental principles of national and international Intellectual Property (IP) law as part of the global system of trade law

LR-3: Acquire tools, techniques and methods for the management of projects, in particular in international and intercultural context.

Workload

Total 180h, hereof 75h contact hours, 105h homework and self-studies (hereof 65 during module, 40 in preparation of module)

Controls of Success In MM 4 (4.4)	Modality of Examination	Performance and Duration of Examination	Prerequisites for exam-participation	Examination Period	Graded
4.4.1 Technology Driven Innovation	Examination of another kind	Presentation of Case Study, approx. 15 minutes per candidate	None	During course	Ye
4.4.2 International Intellectual Property Law	Study achievement	None	None	-	No
4.4.3 Project Management	Examination of another kind	Presentation of Case Study, approx. 15 minutes per candidate	None	During course	Yes
4.4.4 Multi-Project Management in an international setting	Study achievement	None	None	-	No
Grading: The module grade shall be considered proportionally to the credits assigned to the courses.					

4.4.1 Technology Driven Innovation

Course Name			
Technology Driven Innovation			
Semester	Module Type	Allocated to the following Module	Lecturers
2	Compulsory (course is assigned to student by examination board)	Innovation and Projects	Prof. Dr. Orestis Terzidis
Recurrence	Mode of Teaching	Workload	Credit Points for Course
Each summer semester	Lectures, action learning, case studies	Total 72h, hereof 30h contact hours, 42h homework and self-studies	2,4
Overall Course Objectives			
Understanding the unique nature of technology driven innovation and be able to apply suitable tools, techniques and methods to succeed.			
Learning Targets			
Participants ▪ gain competencies of the principles and instruments of a technology driven innovation.			

▪ learn how to differentiate market pull and technology push methods to drive innovation. ▪ experience a technology driven innovation process.
Course Content
▪ Technology Push and Market Pull ▪ The Technology Application Selection (TAS) Process ▪ Technology Characterization ▪ Application Ideation ▪ Value Profile of Technology Applications ▪ Application Selection
Literature
▪ R.C. Dorf, T.H. Byers, Technology Ventures – From Idea to Enterprise., (McGraw Hill 2008) ▪ T.N. Duening, R. D. Hisrich, M. A. Lechter, Technology Entrepreneurship, (Elsevier 2015) ▪ E. Ries, The Lean Startup (Crown Business 2011) ▪ A. Osterwalder, Y. Pigneur, Business Model Generation (Wiley 2010) ▪ B. Dorf, S. Blank, The Startup Owner's Manual (Ranch 2013) ▪ C. Volkmann, K. O. Tokarski, Entrepreneurship (German) (UTB 2006) ▪ U. Fueglistaller, C. A. Müller, T. Volery, Entrepreneurship (Springer-Gabler 2015) ▪ Peter Drucker, Entrepreneurship & Innovation (Routledge 1984/2015) ▪ W. Runge, Technology Entrepreneurship, KIT Scientific Publishing (2014) L. Vogel, O. Terzidis, Methods in Technology Push Development, G-Forum (2016), Paper to appear in Springer Series on Entrepreneurship in Spring 2018
Prerequisites for participation in course
Basic work experience in innovation and project management.
Modality of Exam
See 4.4

4.4.2 International Intellectual Property Law

Course Name			
International Intellectual Property Law			
Semester	Module Type	Allocated to the following Module	Lecturer
2	Compulsory (course is assigned to student by examination board)	Innovation and Projects	Sven Jacobs
Recurrence	Mode of Teaching	Workload	Credit Points for Course
Each summer semester	Lectures and exercises	Total 18h, hereof 7,5h contact hours, 10,5h homework and self-studies	0,6

Overall Course Objectives
The course aims at a general understanding of the mechanisms of international IP law, in particular, how the international system is built on the basis of the notion of territoriality and national law.
Learning Targets
Participants ▪ hold detailed knowledge of the main rights of intellectual property. ▪ analyze and evaluate more complex issues and adds them to a legal solution. ▪ transform the legal fundamentals in contracts about the usage of intellectual property and solve more complex violation cases. ▪ know and understand the basics of legal application procedures and have a wide overview of the legal matters caused by the internet.
Course Content
In international business relations, intellectual property plays an ever increasing role. In innovative industries and in the information society, patents, trademarks and copyrights often constitute the most valuable asset of a firm. Knowledge of how the international IP system works, how IP can be protected beyond national boundaries, is therefore an important part of managing problems of law and contracts. The course gives an overview of the fundamental principles of international Intellectual Property (IP) law as part of the global system of international trade law. The mechanisms of international protection by registration rights (patents, trademarks) and non-registration rights (copyright) are explained. The course focuses both on the legal rules and mechanisms in place and on the underlying philosophies of unification and harmonization of conflicting IP policy options and aims. The course also highlights institutional aspects of the WTO/TRIPS-system and of European harmonization in the area of IP.
Literature
▪ Goldstein, International Intellectual Property Law, Foundation Press, New York, 2001 (or later edition, if available at the time of the course) ▪ WIPO Intellectual Property Handbook – Policy, Law and Use, 2nd edition, Geneva, 2004. Wipo Publication No. 489(E).
Prerequisites for participation in course
Participants should have some basic knowledge and working experience in intellectual property (IP) law. Specialized knowledge in at least one of the major IP rights (patents; trademark; copyright) is advisable, but not a prerequisite.
Modality of Exam
See 4.4

4.4.3 Project Management

Course Name
Project Management

Semester	Module Type	Allocated to the following Module	Lecturers
2	Compulsory (course is assigned to student by examination board)	Innovation and Projects	Prof. Dr. Orestis Terzidis Dr. Abilio Avila
Recurrence	**Mode of Teaching**	**Workload**	**Credit Points for Course**
Each summer semester	Lectures, action learning and case studies	Total 54h, hereof 22,5h contact hours, 31,5h homework and self-studies	1,8

Overall Course Objectives

Understand the general approach in project management for managing single and multiple projects. Learn how to plan, initiate and execute projects.

Learning Targets

Participants

- gain competencies of the principles and instruments of project management.
- gain skills to plan, initiate and execute projects.
- learn how to manage competing objectives and stakeholders.
- gain knowledge of various methods and procedures of project management and project controlling in a global context.

Course Content

- Fundamentals of Project Management
- Tools, Techniques and methods for the management of each phase of the project life cycle
- Traditional Project Management vs. Agile Project Management

Literature

- A Guide to the Project Management Body of Knowledge (PMBOK® Guide)—Fifth Edition, Project Management Institute
- The Fast Forward MBA in Project Management, Eric Verzuh
- Agile Product Management with Scrum: Creating Products That Customers Love, Addison-Wesley, Roman Pichle
- Scrum Guide 2013, Ken Schwaber, Jeff Sutherland
- Designing for Growth: A Design Thinking Tool Kit for Managers (Columbia Business School Publishing), Jeanne Liedtka, Tim Ogilvie
- Operations Research, Stefan Nickel, Oliver Stein, Karl-Heinz Waldmann, 2014, Springer-Lehrbuch
- B.P. Lientz, K.P. Rea: International Project Management, 2002

Prerequisites for participation in course

Professional basic knowledge in project management, such as project planning, risk assessment for projects and project controlling. Open-mindedness.

Modality of Exam

See 4.4

4.4.4 Multi-Project Management in an International Setting

Course Name			
Multi-Project Management in an International Setting			
Semester	Module Type	Allocated to the following Module	Lecturer
2	Compulsory (course is assigned to student by examination board)	Innovation and Projects	Dr.-Ing. Robert Landwehr
Recurrence	Mode of Teaching	Workload	Credit Points for Course
Each summer semester	Lectures, exercises and case studies	Total 36h, hereof 15h contact hours, 21h homework and self-studies	1,2

Overall Course Objectives

Because of the growing importance of project work and the increasing internationalization of projects, this course focuses on complex multi-project management approaches in global environment. The content of the course “Project Management” is extended by introducing methods and tools for managing single and multiple projects. Another point of focus is the organization and the financing of international projects. The content of the course is complemented by industrial examples to provide a practical reference.

The concerted aim is to impart the basic knowledge of project, development and innovation management.

Learning Targets

Participants

- gain knowledge of various methods and procedures of project management and project controlling in a global context.
- are able to analyze problem areas of project management in international and intercultural coherences and to specifically contribute to the improvement of project management in an intercultural environment.
- are able to structure a project portfolio in critical and confusing situations and to make proposals to the top-management about the evaluation and selection or prioritization of projects.
- are capable to systematically establish and apply a multi-project management system including related tools and processes (including project portfolio analysis, program management, risk evaluation, interdependency analysis etc.) with the aid of the mediated knowledge in a business (respectively at a location).

Course Content

- Identification of the main characteristics and problems of international single and multi- project management
- Introduction of methods and tools for multi-project management
- Discussion of the organization and financing as well as the cultural aspects of international single and multi-project management
- Analysis of real world business cases

Literature

B.P. Lientz, K.P. Rea: International Project Management, 2002

Owen J. Murphy: International Project Management; South-Western Pub 2005; ISBN: 0324203020
Prerequisites for participation in course
No prerequisites required.
Modality of Exam
See 4.4

4.5 Strategy and People

Module Name			
Strategy and People			
Semester	Subject	Module Supervisor	Credit Points for Module
3	Management	Prof. Dr. Petra Nieken	6

Module Content

In today's rapidly changing business environments managers constantly face new challenges regarding business strategies while at the same time they have to ensure to keep their employees motivated and committed to the companies' goals. The majority of companies have explicitly HR driven strategies as the motivation of their employees, their commitment and their creativity are core factors for the company's success.

The module "Strategy and People" combines business strategy and corporate law with current challenges of managing organizations, human resource strategy, and leadership concepts. It introduces students to the overall process of strategic management such as strategy formulation, analysis and evaluation. Students learn how to identify and analyze sources of competitive advantage and formulate strategies for different company levels. In a second step, students get insights into business and corporate law including corporate governance and compliance issues that shape economic decisions. In a third step, strategic HR Management shows how strategic decisions are linked to HR practices as it is crucial that the employees understand and support the company's goals. Understanding how individuals and teams behave within a company and how incentive systems and performance measurement influence performance will be main topics of this module. The impact of digital transformation, global teams and diversity a well as selected leadership concepts will be discussed and practical training will be provided.

The module provides evidence based knowledge about core tasks of each manager. Game theoretic elements, behavioral approaches as well as evidence based management concepts and data-driven approaches provide a structured and rigorous framework that enables the students to apply tools and concepts to a wide variety of business situations. Case studies and class room experiments ensure a hands-on approach in handling complex information and datasets that guarantees a strong link to practice. After the course, students will be able to analyze and shape strategy as well as implement it while ensuring to keep their employees motivated in a fast changing environment.

Learning Results (LR)

LR 1: Understanding of central concepts of strategic management, strategy planning and implementation. Knowledge of corporate and business law and its impact on business strategy.

LR 2: Knowledge about the strong interaction between business strategy, human resources and business success. Understanding how incentive systems, corporate guidelines, and behavior influence the motivation and performance of the workforce.

LR 3: Detailed knowledge of business concepts, economic concepts, HR practices, and leadership concepts. Ability to use this knowledge in day-to-day management situations.

Workload

Total 180h, hereof 75h contact hours, 105h homework and self-studies (hereof 65 during module, 40 in preparation of module)

Controls of Success In MM 5 (4.5)	Modality of Examination	Performance and Duration of Examination	Prerequisites for exam-participation	Examination Period	Graded
4.5.1 Strategic Management	Examination of another kind	Presentation of Case Study, approx. 15 minutes per candidate	None	During course	Yes
4.5.2 Managerial Economics	Study Achievement	None	None	-	No
4.5.3 Business Organization and Corporate Law	Written examination	60 minutes	None	At the end of the course week	Yes
4.5.4 Strategic Human Recourse Management	Examination of another kind	Presentation of Case Study, approx. 15 minutes per candidate	Case Study (group work)	During course	Yes
4.5.5 Leadership and Conflict Management	Study Achievement	None	None	-	No
Grading: The module grade shall be considered proportionally to the credits assigned to the courses.					

4.5.1 Strategic Management

Course Name			
Strategic Management			
Semester	Module Type	Allocated to the following Module	Lecturers
3	Compulsory (course is assigned to student by examination board)	Strategy and People	Prof. Dr. Kerstin Fehre
Recurrence	Mode of Teaching	Workload	Credit Points for Course
Each winter semester	Dozent	Total 36h, hereof 15h contact hours, 21h homework and self-studies	1,2
Overall Course Objectives			
Major course objectives are to explain the process of strategic management and to analyze business situations from the internal and external perspective. The formulation of strategies on the business unit and on the corporate level and the evaluation of strategic options based on competitive advantages are introduced and discussed. Furthermore, a major objective is to access existing business portfolios from a strategic perspective.			
Learning Targets			

Participants ▪ are able to describe central concepts of strategic management alongside the ideal-typical strategy process. ▪ are able to undertake internal and external strategic analyses (e.g. SWOT Analysis) with the goal of strategy formulation. ▪ understand the classical concepts and sources of competitive advantages as well as their meaning for the formulation ofcompetitive and business strategies. ▪ are able to formulate strategies at a company level and at a business unit level. ▪ understand the central principles of strategy evaluation and strategy implementation as well as the classical concepts of change management.
Course Content
The course introduces the overall process of strategic management containing strategic analysis, strategy formulation, strategy evaluation based on competitive advantage, and portfolio strategy. The overall process is used as the structuring element, each step will be analyzed and explained in detail. In addition, students learn and experience the most important concepts of strategy formulation in oligopolies. A special emphasis is put on the integration, discussion and application of the frameworks. Several case studies will confirm the attained knowledge.
Literature
Robert M. Grant: Contemporary Strategy Analysis, Blackwell, 7th ed. 2010
Prerequisites for participation in course
No prerequisites required.
Modality of Exam
See 4.5

4.5.2 Managerial Economics

Course Name			
Managerial Economics			
Semester	Module Type	Allocated to the following Module	Lecturer
3	Compulsory (course is assigned to student by examination board)	Strategy and People	Prof. Dr. Clemens Puppe
Recurrence	Mode of Teaching	Workload	Credit Points for Course
Each winter semester	Dozent	Total 18h, hereof 7,5h contact hours, 10,5h homework and self-studies	0,6
Overall Course Objectives			
The objective of the course is to provide a rigorous analysis of the basic determinants of labour supply and incentives at the workplace. Particular attention is given to recent developments in the application of behavioral economics to organisational			

design.
Learning Targets
Participants understand the fundamental concepts of microeconomic theory and behavioral economics relevant to organisational and contract design. The participants are able to infer the behavioral implications of the theoretical concepts and can apply them in real life contexts.
Course Content
Demand for leisure time and the structure of labor supply, symmetric versus asymmetric information models, efficiency wages, monetary versus non-monetary incentives, job market signalling.
Literature
▪ R. Gibbons, A Primer in Game Theory, 1992. ▪ R. Pindyck & D. Rubinfeld, Microeconomics, 9th Edition, 2018.
Prerequisites for participation in course
No formal prerequisites, but basic knoweldge of proabability theory and calculus will be helpful.
Modality of Exam
See 4.5

4.5.3 Business Organization and Corporate Law

Course Name			
Business Organization and Corporate Law			
Semester	Module Type	Allocated to the following Module	Lecturer
3	Compulsory (course is assigned to student by examination board)	Strategy and People	Prof. Dr. Martin Schulz
Recurrence	Mode of Teaching	Workload	Credit Points for Course
Each winter semester	Lectures and case studies	Total 36h, hereof 15h contact hours, 21h homework and self-studies	1,2

Overall Course Objectives
Participants ▪ will understand the relevance of law for business organizations and their stakeholders (also in cross border cases). ▪ gain insight into important forms of business organizations (including corporate governance aspects). ▪ learn central issues of business law and corporate compliance (including managerial liability and legal risk management).

▪ will recognize the interdependence of corporate governance and business law within a globalized economy.
Learning Targets
Participants will understand the impact of law on entrepreneurial activities and become familiar with important forms of business organizations. They learn how to deal with corporate law issues and relevant aspects of corporate governance and compliance management (including cross border elements). Participants learn how to structure and communicate legal issues in international business law cases.
Course Content
This course provides an insight into important business law issues and legal risk management relevant to managerial practice including corporate governance and compliance issues. After outlining the German corporate legal framework, we will discuss some crucial issues of international and European business law, such as the law applicable to corporations engaged in cross-border activities. We will analyze typical cases in corporate practice with a special focus on the role and responsibility of managers. Key practical issues such as the choice of suitable business forms, corporate governance and compliance issues as well as the liability of shareholders and managers will also be discussed and analyzed.
Literature
▪ Kraakman, Reinier et al., The Anatomy of Corporate Law - A Comparative and Functional Approach, 3rd edition Oxford 2017. ▪ Schulz, Martin/ Wasmeier, Oliver. The Law of Business Organizations – A Concise Overview of German Corporate Law, Heidelberg 2012. ▪ Bagley, Winning Legally, How to use the law to create value, marshal resources and manage risk, Boston 2005.
Prerequisites for participation in course
A basic knowledge of German as well as basic knowledge of legal concepts (such as contracts) is helpful.
Modality of Exam
See 4.5

4.5.4 Strategic Human Resource Management

Course Name			
Strategic Human Resource Management			
Semester	Module Type	Allocated to the following Module	Lecturer
3	Compulsory (course is assigned to student by examination board)	Strategy and People	Prof. Dr. Petra Nieken
Recurrence	Mode of Teaching	Workload	Credit Points for Course
Each winter semester	Lectures, case study, project wirk, classroom	Total 54h, hereof 22,5h contact hours,	1,8

	experiment	31,5h homework and self-studies	

Overall Course Objectives

The course aims at a fundamental understanding of the challenges of human resource management processes and their link to strategic decision making. It combines evidence based management concepts, behavioral economics, and data-driven approaches to provide a rigorous framework that enables students to apply HRM tools and practices. An overview of state-of-the art methods and research topics in HRM is provided.

Learning Targets

Participants will be made familiar with relevant challenges of human resource management and selected aspects of leadership and will gain insight into current research on behavior in organizations. The course enables students to understand and analyze strategic situations regarding individual behavior and human resource development in organizations.

Course Content

Today the majority of companies have explicitly HR driven strategies as the motivation of their employees, their commitment and their creativity are core factors for the company's success. This course shows how strategic decisions are linked to HRM and covers various topics of human resource management and leadership in organizations. Evidence based management concepts, concepts from behavioral economics, and data-driven approaches will be complemented by classroom experiments and empirical research results based on company as well as laboratory data. By introducing participants to evidence-based HR-management, they become familiar with current attempts to measure the success of HR development instruments.

We will cover topics such as linking HRM processes to the company's strategy, career and talent management, performance appraisal systems, employee motivation, and company training. Participants will work in teams on case studies that are distributed before the course starts. These real-world examples offer insights into practical HR-issues and leadership problems and illustrate a variety of challenges of HR management.

Literature

- Cascio, W.F.: Managing Human Resources, McGraw-Hill, 2013
- Lazear, E. P. and M. Gibbs: Personnel Economics in Practice. John Wiley & Sons, 2015.
- Huselid, M.A., Becker, B.E. and Beatty, R.W. (2005): The workforce scorecard: Managing human capital to execute strategy. Harvard Business School Press.
- Northouse, Peter G. (2015): Leadership: Theory and Practice, SagePublications

Prerequisites for participation in course

No prerequisites required.

Modality of Exam

See 4.5

4.5.5 Leadership and Conflict Management

Course Name

Leadership and Conflict Management

Semester	Module Type	Allocated to the following Module	Lecturer

3	Compulsory (course is assigned to student by examination board)	Strategy and People	Dr.-Ing. Tobias Kunkel
Recurrence	Mode of Teaching	Workload	Credit Points for Course
Each winter semester	Dozent	Total 36h, hereof 15h contact hours, 21h homework and self-studies	1,2

Overall Course Objectives

Participants acquire a holistic understanding of the complexity of leadership behavior. They are able to critically reflect underlying mechanisms and assess the appropriateness of different leadership styles for different situations. In addition, they have an insight into the emergence of conflicts and know methods to solve them constructively.

Learning Targets

Participants

- know important psychological basics of social interaction and communication.
- acquire knowledge of different leadership approaches and are able to compare them critically.
- learn how to apply conflict solving methods.
- are encouraged to reflect on their own leadership behavior.

Course Content

- Fundamentals of social psychology
- Fundamentals of communication
- Leadership theories
- Methods and models for dealing with conflicts

Literature

- Aronson, E., Wilson, T. D. & Akert, R. M. (2013). *Social Psychology* (8. Aufl.). Boston: Pearson.
- Nerdinger, F. W., Blickle, G. & Schaper, N. (2014). *Arbeits- und Organisationspsychologie* (3. Aufl). Berlin, Heidelberg: Springer.
- Schulz von Thun, F. (2010). *Miteinander reden* (48. Aufl.). Reinbek: Rowohlt Taschenbuch-Verlag.
- Winkler, I. (2010). *Contemporary leadership theories. Enhancing the understanding of the complexity, subjectivity and dynamic of leadership*. Heidelberg, New York: Physica-Verlag.

Prerequisites for participation in course

Successful participation in the lecture „Project Management".

Modality of Exam

See 4.5

5 Description of the Engineering Modules

5.1 Processes, Methods and Tools of Systems Engineering

Module Name			
Processes, Methods and Tools of Systems Engineering			
Semester	Subject	Module Supervisor	Credit Points for Module
1	Engineering	Prof. Dr.-Ing. Eric Sax	6

Module Content

At the beginning an introduction to embedded systems and software engineering is given. Processes, methods and tools from object oriented approaches, via the V-model to agile methods are presented (e.g. Scrum). Among those, HW-/SW-Co-design and rules how to decide which way to go are explained. How to assess these approaches according to process maturity levels (e.g. SPICE and CMMI) and how to follow the demands of safety (relying on ISO 26262 and ASIL) and security is introduced focusing on the transportation industry. Data of sensing and communication are the base for nearly all upcoming new functions of mobility. The importance and methods of their analysis such as anomaly detection is introduced. A case study based on the implementation of a two wheeled transportation platform ("Segway") gives a first impression on the complexity of mechatronics system design.

Learning Results (LR)

LR-1: Knowledge of fundamental characteristics of embedded systems and even cyber physical systems for mobility and industry 4.0 from requirements to realization, either in hardware or in software.

LR-2: Ability to apply methods and tools for data interpretation and analytics

LR-3: Ability to identify the key elements of the two main process models and knowledge of the key concepts for process improvement and process assessments.

LR-4: Experience in working in groups on independent case studies in order to cut through the analysis and draft process of electronic systems and ability to apply methods and tools of model based analysis of hard and software.

LR-5: Knowledge of the fundamentals of virtual design and virtual prototypes and capability to differentiate between causal and no causal modelling.

Workload

Total 180h, hereof 75h contact hours, 105h homework and self-studies (hereof 65 during module, 40 in preparation of module)

Controls of Success In EM 1 (5.1)	Modality of Examination	Performance and Duration of Examination	Prerequisites for Exam-participation	Examination Period	Graded
5.1.1 Fundamentals of Systems Engineering	Written examination	120 minutes	none	At the end of the module	yes

5.1.2 Process Models and Associated Assessments					
5.1.4 Modeling and Simulation					
5.1.5 Big Data Management					
5.1.3 Case Study in Embedded Systems Development (incl. Rapid Prototyping)	Study Achievement	Presentation of Case Study, approx. 15 minutes per candidate	Participation in Case Study	During course	no
Grading: The module grade shall be considered proportionally to the credits assigned to the courses.					

5.1.1 Fundamentals of Systems Engineering

Course Name			
Fundamentals of Systems Engineering			
Semester	Module Type	Allocated to the following Module	Lecturer
1	Compulsory (course is assigned to student by examination board)	Processes, Methods and Tools of Systems Engineering	Prof. Dr.-Ing. Eric Sax
Recurrence	Mode of Teaching	Workload	Credit Points for Course
Each winter semester	Lectures	Total 36h, hereof 15h contact hours, 21h homework and self-studies	1,2
Overall Course Objectives			
The course objective is to introduce the approach of systems engineering in electronic systems development. In the end the students choose the right design method for a characteristic challenge and have all the skills to specify an embedded system, model, simulate and test it.			
Learning Targets			
Participants ▪ understand the analysis and draft process of complex electronic systems development. ▪ are able to apply methods and tools of the model based analysis and the process of hard- and software development. ▪ are able to optimize electronic systems regarding quality, cost and market introduction criteria.			
Course Content			

Embedded Systems are highly complex, safety critical, spatially and functionally distributed electronic control units with hard real time constraints. They interact synchronously with the real nature and get input from sensors and stimulate actuators. All these special conditions for the use of embedded systems will be introduced. Due to those specifics, common approaches for development of software such as in use for desktop applications fail. Precise requirements definition, specification, design and test processes are far more important. An embedded system can't be accessed or updated during operation. No patch or bug fix can be implemented without a lot of efforts such as a recall of thousands of products. Modeling, simulation and hardware-in-the-loop testing (HiL) support these processes and computer aided design tools help as well to a certain extend. Shorter development times, lower product costs while still assuring high quality are further constraints which will be discussed in that lecture. As a consequence, rapid control prototyping (RCP) and agile development are introduced as well. And design techniques such as used in the Unified Modeling Language (UML) will show how early executables on desktop level can push the embedded systems design. Standards for embedded systems design such as introduced in AUTOSAR and OSEK and ASIL levels complete the content.
Literature
▪ Automotive Software Engineering (Schäuffele/ Zurawka) ▪ Test Process Improvement (Koomen/ Pohl) Project manager (Schelle et al.)
Prerequisites for participation in course
Basic knowledge in electrical engineering, process know how.
Modality of Exam
See 5.1

5.1.2 Process Models and Associated Assessments

Course Name			
Process Models and Associated Assesments			
Semester	Module Type	Allocated to the following Module	Lecturer
1	Compulsory (course is assigned to student by examination board)	Processes, Methods and Tools of Systems Engineering	Frank Blucha
Recurrence	Mode of Teaching	Workload	Credit Points for Course
Each winter semester	Lectures	Total 25,2h, hereof 10,5h contact hours, 14,7h homework and self-studies	0,84

Overall Course Objectives
The course objectives are to provide an overview of two world-wide applied process models in industry, CMMI-DEV and AutomotiveSPICE, and their associated assessment methods, to highlight the commonalities as well as the differences and to identify the original intention of these models.
Learning Targets
Participants ▪ are able to identify the key elements of the two process models ▪ are able to locate the relevant processes in the process models ▪ know the major differences between the associated assessment methods ▪ know the key concepts for process improvement and process assessments
Course Content
Embedded systems are getting more complex, the time to market is decreasing, and the pressure on cost is increasing. So the "very flexible" software seems to be a solution to help solving these requests. But the development processes have to fit to these needs. If an organization is not able to handle these conflicting requirements it may lead to quality problems in the product in the field or to big delays in product delivery. As this happened in different industry domains the idea for process models was born to collect good industry practices. CMMI-DEV is one process model which was created to fit to product development in general with focus on software. The course gives an introduction to the history of the model, an overview of the different processes covered, and shows two processes in detail. The overview of the associated assessment method completes the picture of CMMI-DEV. AutomotiveSPICE is another process model which was created to specifically cover embedded product development in Automotive. The course gives an overview of the different processes covered, and shows two processes in detail. The overview of the associated assessment method is also provided. The course shows additionally the commonalities between these two process models and highlights some differences.
Literature
▪ CMMI for Development: Guidelines for Process Integration and Product Improvement (SEI Series in Software Engineering) ▪ Automotive SPICE in Practice Hoermann, Mueller, Dittmann, Zimmer)
Prerequisites for participation in course
Basic knowledge in electrical engineering, process know-how.
Modality of Exam
See 5.1

5.1.3 Case Study in Embedded Systems Development (incl. Rapid Prototyping)

Course Name			
Case Study in Embedded Systems Development (incl. Rapid Prototyping)			
Semester	Module Type	Allocated to the following Module	Lecturers

1	Compulsory (course is assigned to student by examination board)	Processes, Methods and Tools of Systems Engineering	Prof. Dr.-Ing. Eric Sax Andreas Lauber
Recurrence	Mode of Teaching	Workload	Credit Points for Course
Each winter semester	Case studies	Total 28,8h, hereof 12h contact hours, 16,8h homework and self-studies	0,96

Overall Course Objectives

The course objective is to get an expert view into today's design processes and chances by the use of electronics.

Learning Targets

Participants

- work in groups on independent case studies in order to cut through the analysis and draft process of electronic systems.
- are able to apply methods and tools of model based analysis and draft and inspection procedure of hard- and software.
- are able to optimize embedded systems regarding quality and efficiency criteria.

Course Content

Participants complete a final design project as part of a multi-student team. All teams present their project in a verbal presentation to peers, faculty and industry audiences. They define requirements, estimate tasks and resources, engineer design implementations, validate solutions, idea to system perspective, mission analysis, functional analysis, system concept, functional and non-functional requirements specification, project management plan, system design, system analysis, design reviews, risk assessment, safety and security.

The prototype to develop is the control of an one-axle vehicle similar to the Segway product. In the end the participants will integrate all the SW to control the system and even ride that vehicle.

Literature

- Automotive Software Engineering (Schäuffele/ Zurawka)
- Test Process Improvement (Koomen/ Pohl)
- Project manager (Schelle et al.)

Prerequisites for participation in course

Requisites: "Software and Systems Engineering"; User Requirements for System under Development

Modality of Exam

See 5.1

5.1.4 Modeling and Simulation

Course Name			
Modeling and Simulation			
Semester	Module Type	Allocated to the following Module	Lecturer
1	Compulsory (course is assigned to student by examination board)	Processes, Methods and Tools of Systems Engineering	Prof. Dr.-Ing. Sören Hohmann
Recurrence	Mode of Teaching	Workload	Credit Points for Course
Each winter semester	Lectures	Total 54h, hereof 22,5h contact hours, 31,5h homework and self-studies	1,8

Overall Course Objectives

The course objective is to introduce the concept of virtual prototypes on practical examples, to emphasize the characteristics and advantages of different modeling techniques and to show tools to implement virtual prototypes for simulations.

Learning Targets

Participants

- know the fundamentals of virtual design and virtual prototypes
- can name the fundamentals of SysML modeling
- are capable to differentiate between causal and noncausal modelling
- know different tools to implement virtual prototypes
- can apply basic system identification methods

Course Content

The course treats fundamentals of the virtual design of prototypes. To this end, methods to describe systems virtually from different perspectives are taught. In order to model the system context, the use cases and the requirements the system has to fulfill, SysML is introduced and explained at examples. The description of the behavior of the systems is shown by the derivation of mathematical models based on the physics of a system. Herein, noncausal as well as causal modelling techniques are introduced and their advantages and disadvantages are discussed. Moreover, tools are presented to implement causal and noncausal models for simulations. Another focus of the lecture is the parameterization of the mathematical models with least squares estimation and the training of artificial neural networks.

Literature

- Wellstead, P.E.: Introduction to physical system modelling. Academic Press Ltd., 1979
- Marker, D.: Model Theory: An Introduction. Springer, 2002
- Ljung, L.: System Identification: Theory for the User. Prentice Hall, 1998

Prerequisites for participation in course

Basic knowledge in electric circuits and physics

Modality of Exam

See 5.1

5.1.5 Big Data Management

Course Name			
Big Data Management			
Semester	Module Type	Allocated to the following Module	Lecturer
1	Compulsory (course is assigned to student by examination board)	Processes, Methods and Tools of Systems Engineering	Prof. Dr. York Sure-Vetter
Recurrence	Mode of Teaching	Workload	Credit Points for Course
Each winter semester	Lectures	Total 32,4h, hereof 13,5h contact hours, 18,9h homework and self-studies	1,08

Overall Course Objectives

The course teaches the fundamentals of Big Data, including real-world cases, as well as current technical challenges and opportunities of Big Data. Participants will learn the foundational algorithms of large-scale distributed systems. Further, participants will learn how to make use of available technologies to manage Big Data on cloud infrastructures and to perform data analytics tasks. The hands-on sessions will include setting up a cloud environment, and querying and visualizing a large dataset.

Learning Targets

After completing the course, participants are able to:

- explain the V's of Big Data.
- outline the distributed architectures and core components used in Big Data systems.
- explain Brewer's CAP theorem.
- select NoSQL systems appropriate for given requirements.
- outline the use of similarity metrics for data mapping.
- explain steps involved in large-scale data integration and data analytics.

Course Content

The course presents an overview of methods and technologies related to Big Data including:

- Distributed Systems and Cloud Computing.
- Foundational Big Data Technologies.
- Theory and Practice of NoSQL Systems.
- Big Linked Data.
- Exploiting Similarity Measures for Data Integration.

The course concludes with an outlook on further topics, including data mining and machine learning.

Literature
Jure Leskovec, Anand Rajaraman, Jeff Ullman, Mining of Massive Datasets, http://mmds.org/. AnHai Doan, Alon Halevy, Zachary Ives, Principles of Data Integration, Morgan Kaufmann, 2012.
Prerequisites for participation in course
No prerequisites required.
Modality of Exam
See 5.1

5.2 Systems Design

Module Name			
Systems Design			
Semester	Subject	Module Supervisor	Credit Points for Module
1	Engineering	Prof. Dr.-Ing. Eric Sax	6

Module Content

In order to realize an embedded system a concrete EE-architecture is designed to modularize the complete functionality. Controllers and processors or ASICs and FPGAs will implement the applications and interact among each other. Data Communication Topologies and Technologies (e.g. CAN, Flexray or wireless/car2x, Ethernet) are appropriate for that. The interfaces to the environment are enabled by actuators and sensors. All these technologies will be explained in this module and the vision of mobility of the future is conceptually described.

Learning Results (LR)

LR-1: Knowledge of the interconnection between sensing and acting to enable an automatic support of the driver and to judge and review the quality of different human-machine interacting methods.

LR-2: Ability to gain knowledge in computer architectures with a special focus on embedded systems.

LR-3: Understanding of systems theory, control theory and process automation.

LR-4: Ability to implement the most modern components in complex circuit architecture.

LR-5: Use creativity techniques and latest knowledge about technology and processes to design an innovative future transportations system

Workload

Total 180h, hereof 75h contact hours, 105h homework and self-studies (hereof 65 during module, 40 in preparation of module)

Controls of Success In EM 2 (5.2)	Modality of Examination	Performance and Duration of Examination	Prerequisites for Exam-participation	Examination Period	Graded
5.2.1 Control Systems Development	Oral examination	Approx. 15 minutes per candidate	none	At the end of the course week	yes
5.2.2 Embedded Systems Computer Architecture					
5.2.3 Electronic	Oral	Approx. 15 minutes per	none	At the end of the	yes

Systems Synthesis (Hardware and Software), incl. Case Study	examination	candidate		course week	
5.2.4 Future Vehicle Concept Study					
Grading: The module grade shall be considered proportionally to the credits assigned to the courses.					

5.2.1 Control Systems Development

Course Name			
Control Systems Development			
Semester	Module Type	Allocated to the following Module	Lecturer
1	Compulsory (course is assigned to student by examination board)	Systems Design	Prof. Dr.-Ing. Sören Hohmann
Recurrence	Mode of Teaching	Workload	Credit Points for Course
Each winter semester	Lectures and exercises	Total 36h, hereof 15h contact hours, 21h homework and self-studies	1,2

Overall Course Objectives

The course objective is to introduce the fundamentals of process automation and systems theory. The basics for analyzing dynamic systems are learnt and then used to examine the characteristics and advantages of different controller design methods applied to practical examples.

Learning Targets

Participants

- know the fundamentals of systems theory and process automation,
- know different plane models,
- know Cyber Physical Systems,
- know basic control system simulation with MATLAB/SIMULINK,
- can name and describe the levels of automation,
- understand signal flow diagrams, frequency characteristic and locus curve,
- are capable to differentiate signal based and model based methods and
- can apply basic controller design methods.

Course Content

The course treats fundamentals of systems theory, control theory and process automation. In order the different levels of automation up to Cyber Physical Systems are described. The steps for a model based control system development are presented. To analyze dynamical systems different mathematical and graphical forms of description like signal flow diagrams

are introduced. For systems simulation the fundamentals of working with MATLAB and SIMULINK are shown. Different feedback control design methods for a model based as well as a heuristically control design are demonstrated with practical examples.
Literature
▪ R. Dorf, R. Bishop: Modern Control Systems, 11th edition, Addison-Wesley, 2007 ▪ C. Phillips, R. Harbor: Feedback Control Systems, 4th edition, Prentice Hall, 2007 ▪ M. Blanke, M. Kinnaert, J. Lunze, M. Staroswiecki: Diagnosis and Fault Tolerant Control, Springer Verlag, 2008
Prerequisites for participation in course
Basic knowledge in complex analysis and system modelling
Modality of Exam
See 5.2

5.2.2 Embedded Systems Computer Architecture

Course Name			
Embedded Systems Computer Architecture			
Semester	Module Type	Allocated to the following Module	Lecturer
1	Compulsory (course is assigned to student by examination board)	Systems Design	Dr.-Ing. Oliver Sander
Recurrence	Mode of Teaching	Workload	Credit Points for Course
Each winter semester	Lectures and exercises	Total 54h, hereof 22,5h contact hours, 31,5h homework and self-studies	1,8
Overall Course Objectives			
Master the basics and state-of-the-art computer architectures for embedded systems, their characteristics, application fields, limitations, role in modern system architectures, and an introduction to the hardware-software interface.			
Learning Targets			
Participants ▪ gain fundamental knowledge of current and future processor and microcontroller architectures, ▪ know the architecture, application fields and specific characteristics of modern SoC-based embedded systems, ▪ understand which properties are important for selecting a microcontroller for a given application and ▪ gain knowledge about the hardware-software interface and its characteristics.			
Course Content			

The lecture provides a detailed introduction into computer architectures with a special focus on embedded systems. The knowledge will be applied and trained concurrently in practical lab courses. Focus will be the teaching and understanding of architectural challenges and solution strategies, particularly concerning the time-, cost- and performance-optimized design of embedded hardware/software systems. Specific topics to be covered include: ▪ Fundamentals of processor architecture and classifications ▪ Typical Microarchitectures and optimization techniques ▪ Instruction Set Architecture (ISA) and hardware/software interface ▪ System on Chip (SoC) components and architectures ▪ System design aspects and embedded computers ▪ Complex heterogeneous multicores
Literature
Hennessy & Patterson: Computer Architecture (Elsevier, ISBN: 9780123838728)
Prerequisites for participation in course
Digital Design, Basics of Software Programming
Modality of Exam
See 5.2

5.2.3 Electronic Systems Synthesis (Hardware and Software), incl. Case Study

Course Name			
Electronic Systems Synthesis (Hardware and Software), incl. Case Study			
Semester	Module Type	Allocated to the following Module	Lecturer
1	Compulsory (course is assigned to student by examination board)	Systems Design	Prof. Dr.-Ing. Jürgen Becker
Recurrence	Mode of Teaching	Workload	Credit Points for Course
Each winter semester	Lectures and case study	Total 54h, hereof 22,5h contact hours, 31,5h homework and self-studies	1,8
Overall Course Objectives			
Master the basics and state-of-the-art of hardware/software architectures, their co-design, synthesis and application; apply various algorithmic methods for automated synthesis of microelectronic circuits, handle physical design styles of newest technologies.			
Learning Targets			
Participants			

▪ gain knowledge of current and future hardware and software architectures. ▪ understand Co-Design and integrated characteristics of microelectronic circuits and systems with respective drafting methods.
Course Content
The lecture targets system and circuit synthesis methods, design styles and tools, based on the newest technology options to be available. This knowledge will be applied and trained concurrently in practical lab courses. Focus will be the teaching and understanding of feasible problem and solution strategies, particularly with regard to the time-, cost- and performance-optimized design of embedded hardware/software systems. This includes the training of automated hardware synthesis methods for electronic systems being used in today's design tools. Specific topics to be covered include: ▪ Hardware architectures, ▪ Co-design and partitioning of hardware/software systems; ▪ Fundamental and advanced algorithmic methods for automated synthesis of microelectronic circuits; ▪ Physical design styles of the latest technologies.
Literature
Actual list will be provided e. g. Gerez, Algorithms for VLSI Design Automation, Publisher: John Wiley & Son Ltd; ISBN: 0471984892
Prerequisites for participation in course
Digital design, Fundamentals in hardware architectures, Basics in algorithms
Modality of Exam
See 5.2

5.2.4 Future Vehicle Concept Study

Course Name			
Future Vehicle Concept Study			
Semester	Module Type	Allocated to the following Module	Lecturers
1	Compulsory (course is assigned to student by examination board)	Systems Design	Prof. Dr. rer. nat. Frank Gauterin Dr.-Ing. Martin Gießler
Recurrence	Mode of Teaching	Workload	Credit Points for Course
Each winter semester	Project work	Total 36h, hereof 15h contact hours, 21h homework and self-studies	1,2

Overall Course Objectives
The participants get to know a systemic approach to create a concept of a future oriented road vehicle. They will apply the approach to a selected transport task and will define a specification of basic properties, functionality, and design of a vehicle in supervised group work. The concept should take in to account technical, societal, economical and ecological aspects.
Learning Targets
Participants ▪ know the generic structure of a vehicle concept, ▪ understand the multiple influencing factors on a vehicle concept, ▪ know methods to estimate future transport vehicle requirements, ▪ are able to define a vehicle concept based on a requirement analysis, ▪ know methods to evaluate the resulting concept.
Course Content
Module 1: One lecture session of 1,5 h where motivation, task, methodology and the organization of the workshop are presented and discussed. Within a homework the participants will perform a literature and market research to prepare the next session. Module 2: Two workshop sessions of 7,5 h each where a vehicle concept is developed based on the literature and market research using concept generation methods. At the end of the second session, the elaborated concept will be presented and justified.
Literature
Hoffmann, Peter (Hrsg.): Hybridfahrzeuge - Ein alternatives Antriebssystem für die Zukunft. Wien : Springer-Verlag, 2015. Liebl, Johannes et. al.: Energiemanagement im Kraftfahrzeug - Optimierung von CO2-Emissionen und Verbrauch konventioneller und elektrifizierter Automobile. Wiesbaden: Springer Fachmedien, 2014. Maurer, M., et al.: Autonous Driving - Technical, Legal and Social Aspects. Berlin Heidelberg : Springer-Verlag GmbH, 2016. Onori, S. und Serrao, L., Rizzoni, G.: Hybrid Electric Vehicles - Energy Management Strategies. London Heidelberg New York Dordrecht : Springer, 2016. Pischinger, S. und Seifert, U. (Hrsg.): Vieweg Handbuch der Kraftfahrzeugtechnik. 8. Auflage, Wiesbaden: Vieweg+Teubner Verlag | Springer Fachmedien Wiesbaden GmbH 2011, 2016. Reif, K. (Ed.): Fundamentals of Automotive and Engine Technology. Wiesbaden : Springer Fachmedien, 2014. Tschöke, Helmut (Hrsg.).: Die Elektrifizierung des Antriebsstrangs. Wiesbaden : Springer Vieweg, 2015.
Prerequisites for participation in course
No prerequisites required.
Modality of Exam
See 5.2

5.3 ADAS: Functions of ADAS

Module Name			
ADAS: Functions of ADAS			
Semester	Subject	Module Supervisor	Credit Points for Module
2	Engineering	Prof. Dr. rer. nat. Frank Gauterin	6

Module Content

Advanced driver assistance systems help the driver and the vehicle to drive in a safe, comfortable, and efficient way. They cover a wide range from driver information and recommendation systems up to fully automated driving which does not need a driver any more. Vehicles will become able to perceive and understand their environment, to interact and to negotiate with their environment, to take decisions, to act and react autonomously, to predict the consequences of these decisions, and to learn from the experience made. Together with car-to-car and car-to-infrastructure communication, autonomous transport will redefine the automotive world. Especially in combination with sharing concepts, it will lead to disruptive transport solutions. Autonomous, connected, and shared driving has the potential to improve traffic flow and to reduce traffic congestions and space needed for transport. And it will enable regenerative powered vehicles to make full use of their potential to relieve the environment. Successful future driver assistance systems and automated vehicles will be designed to be attractive und to perfectly meet user's needs and expectations.

EM 3 of the Specialization "Advanced Driver Assistance Systems" (ADAS) will focus on the functions of ADAS.

Learning Results (LR)

LR-1: Understand functions and technology of modern driver assistance systems.
LR-2: Understanding of autonomous and semi-autonomous automotive systems, and the challenges of intelligent systems.
LR-3: Qualification to evaluate and to improve drivability of vehicles.
LR-4: -Basic understanding of the inherent dynamics of traffic flow and of the most typical traffic control mechanisms.
LR-3: Understanding of functions and technology of car-to-x communication systems.

Workload

Total 180h, hereof 75h contact hours, 105h homework and self-studies (hereof 65 during module, 40 in preparation of module)

Controls of Success In EM 3 (5.3)	Modality of Examination	Performance and Duration of Examination	Prerequisites for Exam-participation	Examination Period	Graded
5.3.1 Driver Assistance Systems	Oral examination	Approx. 30 minutes per candidate	none	At the end of the course week	Yes
5.3.2 Auto Control Systems					
5.3.3 Driveability	Oral examination	Approx. 45 minutes per candidate	none	At the end of the course week	yes
5.3.4 Traffic Engineering and					

Control 5.3.5 Car-to-X Communication					
Grading: The module grade shall be considered proportionally to the credits assigned to the courses.					

5.3.1 Driver Assistance Systems

Course Name			
Driver Assistance Systems			
Semester	Module Type	Allocated to the following Module	Lecturer
2	Elective	ADAS: Functions of ADAS	Prof. Dr. Marius Zöllner
Recurrence	Mode of Teaching	Workload	Credit Points for Course
Each summer semester	Dozent	Total 36h, hereof 15h contact hours, 21h homework and self-studies	1,2

Overall Course Objectives

The course provides a comprehensive coverage of modern driver assistance systems from the basics to the description of existing systems and gives an outlook to future solutions. The objective is to give professionals an overview and a good understanding of the sensors and systems for driving comfort and safety in conjunction with well adapted ergonomic solutions for the interaction with the systems.

Learning Targets

Participants

- gain an overview of modern driver assistance systems and a prospect for future solutions.
- develop an understanding for sensors and systems for riding comfort and security in association with ergonomic solutions for the interaction with the systems.
- understand the motivation to support the design of comfort and security of driver assistance systems with sensors.

Course Content

This course gives an overview of Driver Assistance Systems for comfort and safety. It starts with the motivation given by the many fatalities on European roads, shows some statistics and the legal situation. The first part of the course continues with systems for vehicle stabilization, brake- and steering support and infrastructure-based systems as well as systems for passive safety and passenger protection. The second part starts with sensors for the perception of the vehicle environment and continues with passive and active driver assistance systems and safety systems for accident avoidance and mitigation. The course ends with a chapter on related ergonomic requirements and solutions and an outlook for a complete and networked vehicle motion and safety system (VMS) as a prerequisite for highly automated and autonomous driving.

Literature

- Robert Bosch GmbH: Safety, Comfort and Convenience Systems, Wiley, 2006

▪ Bosch: Automotive Handbook 9th2014, ISBN 978-1-119-03294-6 ▪ Winner et. al.: Driver Assistance Systems 3rd ed., Springer Verlag (2015)
Prerequisites for participation in course
Advanced knowledge in electrical engineering.
Modality of Exam
See 5.3

5.3.2 Auto Control Systems

Course Name			
Auto Control Systems			
Semester	Module Type	Allocated to the following Module	Lecturer
2	Elective	ADAS: Functions of ADAS	Prof. Dr.-Ing. Rüdiger Dillmann
Recurrence	Mode of Teaching	Workload	Credit Points for Course
Each summer semester	Lectures and exercises	Total 36h, hereof 15h contact hours, 21h homework and self-studies	1,2

Overall Course Objectives
▪ Overview of autonomous mobile robot architectures. ▪ Introduction to knowledge representation and situation assessment. ▪ Overview of decision making and planning methods. ▪ Semi-autonomous driver assistance systems.
Learning Targets
Participants ▪ get an overview of the autonomic-mobile robot architectures. ▪ gain knowledge of semi-autonomic assistant systems. ▪ understand decision and planning methods. ▪ gain insight into methods of information gathering and the classification of situations of autonomic systems. ▪ develop an understanding for the problems of intelligent systems.
Course Content
This course provides an introduction to autonomous mobile systems with a focus on autonomous cars. The discussion of

several robot architectures founds the basis for the later analysis of methods that enables cars to think about the environment and the consequences of the own actions. The fundamentals of knowledge representation, situation assessment and decision making are illustrated by means of real world examples with an emphasis on stochastic methods for handling uncertainty introduced through the partial observability of the environment. Finally the course gives an outlook on cognitive automobiles that will revolutionize our way of locomotion. The lectures are combined with teamwork exercises and presentations of self-acquired findings.
Literature
S. Thrun, W. Burgard, and D. Fox. Probabilistic Robotics (Intelligent Robotics and Autonomous Agents). MIT press, Cambridge, Massachusetts, USA, 2005.
Prerequisites for participation in course
Basics in system theory, stochastic, formal systems, computational geometry and linear algebra.
Modality of Exam
See 5.3

5.3.3 Driveability

Course Name			
Driveability			
Semester	Module Type	Allocated to the following Module	Lecturer
2	Elective	ADAS: Functions of ADAS	Dipl.-Ing. Sascha Ott
Recurrence	Mode of Teaching	Workload	Credit Points for Course
Each summer semester	Lectures and exercises	Total 36h, hereof 15h contact hours, 21h homework and self-studies	1,2
Overall Course Objectives			
▪ Understanding the importance of drivability for successful innovation of mobile systems. ▪ Knowing the difference between drivability and NVH, although the interaction of both. ▪ Knowing the most important methods to analyze and to rate the drivability behavior. ▪ Be able to apply and to interpret ratings of drivability. ▪ Understanding the feedback of drivability behavior to the complete mobile system and to the pdp. ▪ Knowing the possibilities to improve drivability using up-to-date methods. ▪ This course is related to NVH, Human Factors Engineering and Driver Assistance.			
Learning Targets			
Participants			

▪ learn and apply methods for the analysis and evaluation of vehicle behavior. ▪ gain knowledge of planning and implementation of physical and virtual vehicle behavior tests.
Course Content
The acceptance of innovative vehicle- and powertrain concepts is mostly defined by economical and technical performance figures. Furthermore, the drivability of a mobile-system is just as well important to enable market success of innovative mobile concepts. In this course the interaction inside the mobile system and the interaction between the mobile system and the environment (e.g. traffic, road, climate) belonging to the drivability are analyzed. Based on that the impact of drivability, as a very important part of the system of objectives, inside the product development process (PDP) will be discussed here. As very important tools of validation inside the PDP, existing methods of drivability rating in an objective way are trained in some practical exercises.
Literature
None
Prerequisites for participation in course
No prerequisites required.
Modality of Exam
See 5.3

5.3.4 Traffic Engineering and Control

Course Name			
Traffic Engineering and Control			
Semester	Module Type	Allocated to the following Module	Lecturer
2	Elective	ADAS: Functions of ADAS	Prof. Dr.-Ing. Peter Vortisch
Recurrence	Mode of Teaching	Workload	Credit Points for Course
Each summer semester	Dozent	Total 36h, hereof 15h contact hours, 21h homework and self-studies	1,2
Overall Course Objectives			
Since vehicles are normally driving on roads not alone but are part of traffic streams, it is useful to have a basic understanding of the inherent dynamics of traffic flow and of the most typical traffic control mechanisms. The course will provide this understanding by giving the theoretical background and by using a state-of-the-art tool for traffic flow simulation.			
Learning Targets			

Participants
▪ gain knowledge of traffic flow systems and traffic control systems. ▪ understand the theory of State-of-the-Art tools for traffic flow simulation. ▪ gain competency for the implementation of capacity analysis for highways and centers of communication. ▪ learn and are able to apply the modeling of traffic infrastructure.
Course Content
The course starts by giving the fundamental definitions for the description of traffic flows and investigates their macroscopic characteristics up to first order shockwaves. Then the microscopic side of traffic flows is studied, including three common car-following models. The next subject to study are intersections, where vehicle compete for the right of way. A method for computing the capacity of non-signalized intersections is presented. Finally, the basics of signal control are explained. In the last section of the course, a software tool for microscopic traffic flow is introduced. Practical exercises using this tool will show how it is used to analyze the impact of traffic control measures and to better understand interactions of vehicles in traffic streams.
Literature
▪ Roess, Prassas and McShane: Traffic Engineering, Prentice Hall; 4 edition (July 4, 2010); ISBN-13: 978-0136135739 ▪ Wilhelm Leutzbach: Introduction to the Theroy of Traffic Flow, Springer 1988, ISBN-13: 978-0387171135
Prerequisites for participation in course
No prerequisites required.
Modality of Exam
See 5.3

5.3.5 Car-to-X Communication

Course Name			
Car-to-X Communication			
Semester	Module Type	Allocated to the following Module	Lecturer
2	Elective	ADAS: Functions of ADAS	Dr. Frank Hofmann
Recurrence	Mode of Teaching	Workload	Credit Points for Course
Each summer semester	Lectures and exercises.	Total 36h, hereof 15h contact hours, 21h homework and self-studies	1,2
Overall Course Objectives			

The course objectives are to provide an overview of car-to-car and car-to-infrastructure communication systems and possible applications, to understanding the overall system requirements and challenges and the standardized system architecture as well as the employed communication principles and protocols.

Learning Targets

Participants

- get an overview over Car-to-Car and Car-to-Infrastructure communication systems and possible applications.
- acquire an understanding of the system requirements, the existing fundamental challenges,
- know how the standardized system architecture is going to solve all these challenges.

Course Content

In the future, Car-to-Car and Car-to-Infrastructure communication will be the basis for applications that increase traffic safety and traffic efficiency. In this course, participants will become familiar with the technical elements and scientific challenges behind car-to-car and car-to-infrastructure communication.

The course will cover applications, proposed communication systems and protocols. The standardization activities with respect to the “Wireless Access in Vehicular Environments” (IEEE 802.11p and 1609) will be addressed in detail as well, including up-to-date results of various project activities around the globe. In addition, security, privacy and incentive aspects will be covered.

Literature

- H. Hartenstein and K. Laberteaux (Editors), VANET - Vehicular Applications and Inter-Networking Technologies, John Wiley & Sons, 2010
- H. Hartenstein and K. Laberteaux, A tutorial survey on vehicular ad hoc networks, IEEE
- Communications Magazine, vol. 46, no. 6, pp. 164-171, June 2008

Prerequisites for participation in course

Basics in computer networking, basics in wireless communications, basics in distributed systems

Modality of Exam

See 5.3

5.4 E-Mobility: Political and Technical Framework

Module Name			
E-Mobility: Political and Technical Framework			
Semester	Subject	Module Supervisor	Credit Points for Module
2	Engineering	Prof. Dr.-Ing. Martin Doppelbauer	6

Module Content

Global emissions scenarios studies highlight the importance of the transportation sector for climate change mitigation. Therefore, Powertrain technologies and topologies must be assessed with regard to the overarching goal of climate and environmental protection. Policy plays an important role as it provides the framework conditions within which the markets are moving.

Transportation markets and their specific mechanisms, trends in travelling demand and economy as well as political regulations are further topics.

New concepts and new infrastructure are needed for the local supply of electric energy to plug-in and full electric vehicles. Energy management starts with the generation of energy, which should ideally be done locally, and includes topics like energy storage and energy distribution, as well as intelligent new charging concepts that are geared towards momentary electricity production and consumption.

The topic of NVA (noise, vibration, harshness) becomes increasingly challenging as the reduced noise level of electric drives makes sound sources audible that have hardly played a role in conventional vehicles. Charging technologies and recuperation strategies play an important role in increasing the limited driving range.

Engineering module 3 gives an overview of the boundary conditions for electric and hybrid electric traction vehicles, including transportation market policies, well-to-wheel climate impact analysis, energy management and distribution.

Learning Results (LR)

LR-1: Thorough understanding of the technical and political boundary conditions of the electricity and transportation markets.

LR-2: Qualification to evaluate vehicle concepts based on total cost of ownership and well-to-wheel CO2 emission scenarios.

LR-3: Thorough understanding of the technical boundary conditions of electric energy distribution and charging systems, including on-board energy management.

LR-4: Being able to analyze market opportunities for future projects.

LR-5: Qualification to thoroughly understand and optimize topics of noise, vibration and harshness for electric vehicles.

Workload

Total 180h, hereof 75h contact hours, 105h homework and self-studies (hereof 65 during module, 40 in preparation of module)

Controls of Success In EM 3 (5.4)	Modality of Examination	Performance and Duration of Examination	Prerequisites for Exam-participation	Examination Period	Graded
5.4.1 Introduction into Requirements,	Study Achievement	None	None	-	No

Solutions and Challenges of E-Mobility					
5.4.2 Case Study					
5.4.3 CO2-Balances: Well to wheel	Written examination	60 minutes	None	At the end of the course week	Yes
5.4.4 Transportation Markets and Policy	Oral examination	Approx. 20 minutes per candidate	None	At the end of the course week	Yes
5.4.5 Energy Distribution					
5.4.6 Energy Management	Oral examination	Approx. 30 minutes per candidate	None	At the end of the course week	Yes
5.4.7 Noise, Vibration and Harshness for E-Mobility					
Grading: The module grade shall be considered proportionally to the credits assigned to the courses.					

5.4.1 Introduction into Requirements, Solutions and Challenges of E-Mobility

Course Name			
Introduction into Requirements, Solutions and Challenges of E-Mobility			
Semester	Module Type	Allocated to the following Module	Lecturer
2	Elective	E-Mobility: Political and Technical Framework	Prof. Dr.-Ing. Martin Doppelbauer
Recurrence	Mode of Teaching	Workload	Credit Points for Course
Each summer semester	Lectures and discussions	Total 7,2h, hereof 3h contact hours, 4,2h homework and self-studies	0,24
Overall Course Objectives			
The course objective is to get a structured holistic understanding of sustainable mobility systems.			
Learning Targets			
Participants: • gain knowledge of national and international climate policies and the Paris climate agreement of 2015 • know renewable energy sources and energy carriers • gain knowledge of limited and renewable energy sources and their availability • get a comprehensive overview of existing and new drive train topologies			

• understand the challenges in the distribution (infrastructure) of renewable energy carriers
Course Content
This course will give an introduction and thorough overview on the different future scenarios for sustainable, environmental friendly individual mobility solutions. This includes energy carrier production from primary energy sources, energy carrier distribution infrastructure, well-to-wheel analysis of the environmental footprint and life cycle analysis. The participants will be introduced to technical solutions, CO2 emissions and associated costs. Social and user needs for individual mobility are discussed in detail. Various technical solution for drive trains (electrical, combustion engine, hybrid) and energy storage systems (batteries, hydrogen, natural and synthetic gas) are introduced and compared, including the required infrastructure. The course is supplemented by a case study, where the students will compare possible future scenarios regarding CO2 footprint, cost of infrastructure, cost of vehicles and cost per km.
Literature
Lecture notes (powerpoint presentation) and case studies in printed form. Recent studies and papers will be provided at the lecture.
Prerequisites for participation in course
Basics in Electrical and Mechanical Engineering
Modality of Exam
See 5.4

5.4.2 Case Study

Course Name			
Case Study			
Semester	Module Type	Allocated to the following Module	Lecturer
2	Elective	E-Mobility: Political and Technical Framework	Prof. Dr.-Ing. Martin Doppelbauer
Recurrence	Mode of Teaching	Workload	Credit Points for Course
Each summer semester	Lectures, exercises and team work	Total 10,8h, hereof 4,5h contact hours, 6,3h homework and self-studies	0,36
Overall Course Objectives			
The participants get a more detailed understanding of sustainable mobility systems and compare different solutions.			
Learning Targets			
Participants: • Will analyse literature, studies, internet and newspaper articles to gather knowledge on drive train topologies, energy			

carriers and energy distribution • Learn to evaluate and assess information sources • Get a more detailed, holistic overview of different options for future mobility systems
Course Content
In this case study, student groups will assess possible future mobility solutions regarding ecological and economical aspects. These include: Battery electric vehicles, full-hybrid electric vehicles, hydrogen fuel-cell vehicles, LPG/CNG combustion vehicles with bio-fuels or synthetic fuels (power-to-gas). Tasks for each Group: 1) Describe the technical solution in detail (drive train of the car, on-board energy storage, energy carrier distribution, energy carrier production) 3) Determine the energy demand (well-to-wheel) of the selected drive train topology for a give scenario (driving cycle) 4) Determine the total amount of energy needed to run all vehicles in a given country with the selected drive train 5) Show practical solutions, how to obtain the required energy in an environmental friendly way 6) Assess the cost of the drive train and energy storage compared to today's cars with combustion engines 7) Determine the cost of the infrastructure (production of the energy carrier, cost of distribution) 8) Determine the driving cost per km All groups: Compare your findings with the other groups. Which technology is most likely to be successful?
Literature
Lecture notes (powerpoint presentation) and case studies in printed form. Recent studies and papers will be provided at the lecture.
Prerequisites for participation in course
Basics in Electrical and Mechanical Engineering
Modality of Exam
See 5.3

5.4.3 CO2-Balances: Well to wheel

Course Name			
CO2-Balances: Well to wheel			
Semester	Module Type	Allocated to the following Module	Lecturers
2	Elective	E-Mobility: Political and Technical Framework	Dr. Stefan Pfahl PD. Dr. rer. pol. Patrick Jochem
Recurrence	Mode of Teaching	Workload	Credit Points for Course

Each summer semester	Dozent	Total 36h, hereof 15h contact hours, 21h homework and self-studies	1,2

Overall Course Objectives

The lecture imparts the basic knowledge about the main relevant drivers concerning the market penetration of new drive trains in the passenger car segment. It lays the ground understanding for the fundamental interactions between these drivers. It thus enables to develop the ability to judge the strategic potentials in the field of sustainable mobility systems.

Learning Targets

Participants

- gain competencies to rate the strategic potentials in the area of low- and zero-CO_2-vehicles
- gain basic knowledge of drivers for low- and zero-CO_2-vehicles and their interaction

Course Content

To evaluate the market potentials of low- or zero-CO2 emission-vehicles an interdisciplinary approach imparts the main aspects of technological mitigation potentials, well to wheel emissions, technology costs, energy prices, regulations, mobility services and costumer behavior. It provides a modeling approach to structure the complex subject.

Literature

None

Prerequisites for participation in course

No prerequisites required.

Modality of Exam

See 5.4

5.4.4 Transportation Markets and Policy

Course Name

Transportation Markets and Policy

Semester	Module Type	Allocated to the following Module	Lecturers
2	Elective	E-Mobility: Political and Technical Framework	Prof. Dr. Kay Mitusch Dr. Eckhard Szimba
Recurrence	**Mode of Teaching**	**Workload**	**Credit Points for Course**
Each summer semester	Lectures and exercises	Total 36h, hereof 15h contact hours, 21h homework and self-studies	1,2

Overall Course Objectives
The course objective is to gain understanding of the complex issues of transport policy.
Learning Targets
Participants ▪ learn to know the economist's perspective on social decisions and markets. ▪ are able to analyze environmental and pricing issues of roads. ▪ get an overview of the demand for e-mobiles and potentially viable business models for e-mobiles. ▪ learn how transport policies and projects are evaluated and how policy instruments for green mobility work.
Course Content
The course starts with a lecture on "Economic Principals" that serves as an introduction or fresh-up on the economic approach to decisions, appraisal, and markets, including the internalization of external costs. The next part provides an overview and analysis of the demand for e-mobility by households and firms and a look at particular Green Mobility business models. After an introduction to economic evaluation methods (e.g., cost-benefit analysis) to assess and compare Green Mobility business models and policies, some typical instruments promoting e-mobility and Green Mobility are discussed.
Literature
▪ Blauwens, G. de Baere, P. and E. van de Voorde: Transport Economics. Antwerpen. 2002. ▪ Flyvbjerg, B.; Bruzelius, N. and W. Rothengatter, 2003: "Megaprojects and risk: an anatomy of ambition", Cambridge: University Press.
Prerequisites for participation in course
No prerequisites required.
Modality of Exam
See 5.4

5.4.5 Energy Distribution

Course Name			
Energy Distribution			
Semester	Module Type	Allocated to the following Module	Lecturer
2	Elective	E-Mobility: Political and Technical Framework	Prof. Dr. Hartmut Schmeck
Recurrence	Mode of Teaching	Workload	Credit Points for Course

Each summer semester	Lectures	Total 18h, hereof 7,5h contact hours, 10,5h homework and self-studies	0,6

Overall Course Objectives

The objective of this course is to provide insights into the special impact of an increasing number of electric vehicles on energy distribution and power system management. In particular, it will address the need for an intelligent use of information and communication systems, tools, and services for building and managing a reliable smart power grid which moves from demand-oriented management to supply-oriented demand management, and will highlight the special requirements and opportunities of vehicle to grid integration.

Learning Targets

Participants

- know about the key properties and requirements of energy distribution and management and about the special challenges of the Energy Transition.
- know about the specific role of ICT in the presence of electrical vehicles and power generation from renewable sources.

Course Content

The course will give an overview of current and anticipated future approaches to the distribution and management of electrical energy and on the particular aspects of integrating the power demand of an increasing number of electrical vehicles into the power system.

The following topics will be covered:

- Structure of the power distribution network (from power generation to power consumption).
- Management tasks and challenges in electrical energy networks.
- Balancing zones, balancing groups, and the tasks of balancing group managers (power schedule planning, the roles of primary, secondary and tertiary balancing power).
- Power mix and the special aspects of power generation from renewable sources (including challenges with respect to the Energy Transition (Energiewende) and the special role of electric vehicles).
- Market structures in the power system (EEX, day-ahead and intra-day trading).
- Information and communication technology in the power system (intelligent metering, communication protocols, energy management and operating systems, privacy issues).
- Demand side management (central and decentralized approaches, increasing the flexibility of power consumption and power supply).
- Intelligent power management for electrical vehicles (charging, discharging, charging station infrastructure, communication protocols for V2G (ISO/IEC 15118, OCPP, OICP), power-aware routing services etc.).

Literature

Based on material related to projects on smart grids and ICT for electric vehicles.

Prerequisites for participation in course

Some knowledge of electrical power systems and of some fundamentals of information and communication technology.

Modality of Exam

See 5.4

5.4.6 Energy Management

Course Name			
Energy Management			
Semester	Module Type	Allocated to the following Module	Lecturers
2	Elective	E-Mobility: Political and Technical Framework	Prof. Dr. rer. nat. Frank Gauterin Dr.-Ing. Michael Frey
Recurrence	Mode of Teaching	Workload	Credit Points for Course
Each summer semester	Lectures and exercises	Total 36h, hereof 15h contact hours, 21h homework and self-studies	1,2

Overall Course Objectives

The lecture provides an overview about requirements and technical solutions for automotive energy management.

Learning Targets

Participants

- know the boundary conditions and requirements on energy management of road vehicles,
- have an overview of technologies and systems for road vehicle energy management,
- know methods to design and to operate energy efficient road vehicles according to the requirements and boundary conditions,
- are familiar with options of energy supply.

Course Content

- General challenges
- Legal requirements
- Requirements of the market
- Use cases
- Vehicle concepts
- Energy consumption
- Energy flow control
- Energy generation and supply

Literature

Junior C, Jänsch D, Dingel O (Eds.), Energy and Thermal Management, Air Conditioning, Waste Heat Recovery: 1st ETA Conference, December 1-2, 2016, Berlin, Germany, Springer, Cham, Switzerland 2017

Liebl J, Lederer M, Rhode-Brandenburger K, Biermann J-W, Roth M, Schäfer H, Energiemanagement im Kraftfahrzeug,

Springer Vieweg, Wiesbaden 2014

Langheim J (Ed.), Energy Consumption and Autonomous Driving: Proceedings of the 3rd CESA Automotive Electronics Congress, Paris, 2014, Springer, Cham, Switzerland 2016

Onori S, Serrao L, Rizzoni G, Hybrid Electric Vehicles: Energy Management Strategies, Springer, London 2016

Watzenig D, Brandstätter B (Eds.), Comprehensive Energy Management – Eco Routing and Velocity Profiles, SpringerBriefs in Applied Sciences and Technology, Cham, Switzerland 2017

Watzenig D, Brandstätter B (Eds.), Comprehensive Energy Management – Safe Adaptation, Predictive Control and Thermal Management, SpringerBriefs in Applied Sciences and Technology, Cham, Switzerland 2018

Prerequisites for participation in course
No prerequisites required.
Modality of Exam
See 5.4

5.4.7 Noise, Vibration and Harshness for E-Mobility

Course Name			
Noise, Vibration and Harshness for E-Mobility			
Semester	Module Type	Allocated to the following Module	Lecturer
2	Elective	E-Mobility: Political and Technical Framework	Prof. Dr. rer. nat. Frank Gauterin
Recurrence	Mode of Teaching	Workload	Credit Points for Course
Each summer semester	Lectures and exercises	Total 36h, hereof 15h contact hours, 21h homework and self-studies	1,2
Overall Course Objectives			
The course objective is to get a NVH related vehicle system understanding and to learn how to design a quiet and comfortable electric vehicle.			
Learning Targets			

Participants are expected to acquire the following knowledge and be able to apply:

- Theory of noise and vibration phenomena
- Properties of human hearing and vibration sensing system
- Noise and vibration analysis tools, methods and optimization strategies
- Trade-offs and challenges
- NVH properties and solutions of electric vehicle components
- NVH component interaction in the vehicle system

Course Content
The lecture addresses both, theory and application examples of automotive noise and vibration of electric vehicles. It starts with the perception of noise and vibration. Second, in a simplified way the vehicle vibration behavior is modeled by one and two degree of freedom systems. The concept of modal analysis is introduced to use the single degree of freedom model also for the description of complex structural vehicle oscillations. Third, a selection of the most important vehicle systems influencing vehicle NVH performance (tire, brake, suspension and drive train) are discussed concerning phenomena, root causes, influencing factors, improvement approaches, and target conflicts.
Literature
Harrison M, Vehicle Refinement, Elsevier, Oxford 2004 Hibbeler R C, Engineering mechanics: dynamics, Pearson, Munich 2016 Sheng, G, Vehicle noise, vibration, and sound quality, SAE International, Warrendale 2012 Wang, Xu (Ed.): Vehicle Noise and Vibration Refinement, Woodhead Publishing Ltd, Abington Hall, UK, 2010.
Prerequisites for participation in course
Basic knowledge of mechanics, dynamics and vehicle technology.
Modality of Exam
See 5.4

5.5 ADAS: Components and Technology of ADAS

Module Name			
ADAS: Components and Technology of ADAS			
Semester	Subject	Module Supervisor	Credit Points for Module
2	Engineering	Prof. Dr. rer. nat. Frank Gauterin	6

Module Content

Modern vehicles are becoming more and more intelligent. Sensors and cognitive control units detect and communicate with the environment, recognize other vehicles and other traffic participants, understand and predict their behaviour, and operate the vehicle autonomously. Based on detailed user, vehicle, road, infrastructure, and traffic data and by using predictive green routing and vehicle operation management, a safe, secure, comfortable, energy and time efficient drive is realized.

Intelligent vehicles need detailed information about their own status and their proximity. This is provided by sensors, often in combination with emitters of electromagnetic waves like radar and light. From the sensor signals information about static and moving objects is derived by mobile perception systems. The automated environmental recognition is not only based on sensor data but also on data perceived by car-to-car, car-to-infrastructure, and car-to-backend communication, as well on knowledge which was learned during previous drives. Appropriate vehicle hard- and software system architecture will allow fast and reliable data processing. IT safety and security systems make sure that missing, incorrect, or counterfeit information in automotive communication will not cause high risk for traffic participants and vehicles. Valid information allows beneficial traffic organization, like platooning, to reduce the traffic space consumption and increase the traffic capacity.

Learning Results (LR)

LR-1: Understanding of automotive radar technology, and optical actors and sensors.
LR-2: Sound knowledge about methods and technology of mobile perception systems.
LR-3: Understand the importance of perception systems for the safety, comfort, and efficiency of ground vehicles.
LR-4: Skills in handling tools and methods for implementing safety and data protection requirements in networked applications.
LR-5: Be familiar with analysis and draft process of automotive electronic systems for automated driving.

Workload

Total 180h, hereof 75h contact hours, 105h homework and self-studies (hereof 65 during module, 40 in preparation of module)

Controls of Success In EM 4 (5.5)	Modality of Examination	Performance and Duration of Examination	Prerequisites for Exam-participation	Examination Period	Graded
5.5.1 Automotive EMC Technology	Oral examination	Approx. 30 minutes per candidate	None	At the end of the course week	Yes
5.5.2 Automotive Lighting					
5.5.3 Mobile Perception Systems	Oral examination	Approx. 30 minutes per candidate	None	At the end of the course week	Yes

5.5.4 IT Safety and Security					
5.5.5 Hands-on Training: Platooning	Study achievement	None	Participation in Training	-	No
Grading: The module grade shall be considered proportionally to the credits assigned to the courses.					

5.5.1 Automotive EMC Technology

Course Name			
Automotive EMC Technology			
Semester	Module Type	Allocated to the following Module	Lecturer
2	Elective	ADAS: Components and Technology of ADAS	Dr. Uwe Reinhardt
Recurrence	Mode of Teaching	Workload	Credit Points for Course
Each summer semester	Lectures and exercises	Total 36h, hereof 15h contact hours, 21h homework and self-studies	1,2

Overall Course Objectives

On the successful completion of the course the participants know the radar principle and its potential for automotive applications. The participants will gather knowledge about system and design requirements of automotive radars and will understand the relation between all relevant system parameters and component specifications and the overall system performance.

Learning Targets

Participants

- understand radar principles and fundamentals.
- acquire knowledge about system and design requirements for automotive radar.
- receive the theoretical background of main radar components.

Course Content

Automotive radar systems have been identified as a significant technology for the improvement of road safety and driving comfort. In this course the participants will become familiar with the technical components and design challenges behind automotive radar.

After an overview of the large variety of radar applications especially in automobiles the first part of the course focus is on the radar principle and all relevant radar frontend components. The second part covers all different radar types used in the automotive industry, followed by methods for target detection, tracking and avoidance of radar interference. Finally, the participants have the opportunity to apply their acquired theoretical radar knowledge to practice in a laboratory experiment.

Literature
▪ M. Skolnik, Radar Handbook, McGraw-Hill, 3rd Edition, 2008. ▪ D. Pozar, Microwave Engineering, John Wiley & Sons, 3rd Edition, 2005. ▪ D. K. Barton, Radar System Analysis and Modeling, Artech House, Inc., 2005.
Prerequisites for participation in course
Basics in Electrical Engineering
Modality of Exam
See 5.5

5.5.2 Automotive Lighting

Course Name			
Automotive Lighting			
Semester	Module Type	Allocated to the following Module	Lecturer
2	Elective	ADAS: Components and Technology of ADAS	Prof. Dr. rer. nat. Cornelius Neumann
Recurrence	Mode of Teaching	Workload	Credit Points for Course
Each summer semester	Lectures	Total 36h, hereof 15h contact hours, 21h homework and self-studies	1,2
Overall Course Objectives			
Modern assisting functions in automotive rely on sensors of different range, often based on electromagnetic radiation (e.g. light, infrared- or microwave radiation). The information that is extracted out of the sensor information steer different kind of actors, including adaptive head lamp systems. Actor sensor systems in automotive lighting enable to drive more save at nighttime and help to reduce traffic accidents. Modern applications in light based assisting systems will be the central part of the course.			
Learning Targets			
Participants ▪ learn the basics of automotive lighting and ELM sensors. ▪ understand the interconnection between sensing and acting to enable an automatic support of the driver. ▪ gain competences for the development of automotive lighting systems. ▪ are able to judge and review the quality of different human machine interacting methods. ▪ gain skills to follow the development in this field of research and application and to judge the safety gain of upcoming lighting systems.			
Course Content			

The lecture Automotive Lighting includes: ▪ Basics of Automotive Lighting and Vision ▪ Basics of Electromagnetic (ELM) Sensor Systems ▪ Human Machine Interaction (HMI) ▪ ELM Sensors in Automotive ▪ Adaptive Lighting Systems ▪ Applications of Sensor-Actor Systems in Light Based Assisting Systems (LBAS)
Literature
Wördenweber, B., Wallaschek, J., Boyce, P., Hoffman, D.D. - Automotive Lighting and Human Vision; Springer 2007 ISBN 978-3-540-36697-3
Prerequisites for participation in course
No prerequisites required.
Modality of Exam
See 5.5

5.5.3 Mobile Perception Systems

Course Name			
Mobile Perception Systems			
Semester	Module Type	Allocated to the following Module	Lecturer
2	Elective	ADAS: Components and Technology of ADAS	Prof. Dr.-Ing. Christoph Stiller
Recurrence	Mode of Teaching	Workload	Credit Points for Course
Each summer semester	Lectures	Total 36h, hereof 15h contact hours, 21h homework and self-studies	1,2
Overall Course Objectives			
The objective of this course is to explain the importance of perception systems for the safety, comfort, and efficiency of mobile machines, to Introduce into the fundamentals of sensor technologies and to provide an overview on methods for scene perception to enable students to assess the uncertainties associated with these.			
Learning Targets			
On successful completion of this course the students understand the principles of radar, lidar, and vision sensors and their potential towards recognition of scene around a mobile. Participants know the basic methods for scene reconstruction und are able to quantify the resulting uncertainties in scene representation. The students have gathered first experience with specific methods for environment perception from exercises and hands-on demonstrations.			

Course Content
This course provides an overview on sensors that allow perceiving the environment of mobiles. The principles of radar, lidar, and video sensors are presented and their strengths and weaknesses are discussed. The lecture focuses on optical sensors, such as cameras and outlines the fundamentals of image acquisition and perspective projection. Fundamental methods for reconstruction of the 3-dimensional scene and the relevant information for navigation from mono- and stereoscopic camera systems are discussed. The lecture provides an outlook towards applications in driver assistance systems and automated driving.
Literature
▪ Maurer, Markus; Stiller, Christoph (eds.): Fahrerassistenzsysteme mit maschineller Wahrnehmung. Heidelberg: Springer-Verlag, 2005 ▪ Winner, Hermann; Hakuli, Stephan; Wolf, Gabriele (eds.): Handbuch Fahrerassistenzsysteme. Wiesbaden: Vieweg + Teubner, 2009, ▪ Thrun, Sebastian; Burgard, Wolfram; Fox, Dieter: Probabilistic Robotics, MIT Press, 2005
Prerequisites for participation in course
Basics in System Theory, Stochastics, and Linear Algebra
Modality of Exam
See 5.5

5.5.4 IT Safety and Security

Course Name			
IT Safety and Security			
Semester	Module Type	Allocated to the following Module	Lecturers
2	Elective	ADAS: Components and Technology of ADAS	Prof. Dr. Jörn Müller-Quade
Recurrence	Mode of Teaching	Workload	Credit Points for Course
Each summer semester	Lectures and exercises	Total 36h, hereof 15h contact hours, 21h homework and self-studies	1,2
Overall Course Objectives			
▪ Knowledge of the cryptographic foundations of IT security. ▪ Understanding of security leaks through case studies. ▪ Development of the ability to mistrust given solutions.			
Learning Targets			
Participants			

- know the theoretical basics as well as basic mechanisms of computer security and cryptography.
- understand the mechanisms of computer security and is able to explain them.
- read and understand current scientific articles.
- evaluate the security of given procedures and recognizes dangers.
- apply mechanisms of computer security in new IT and business environments.

Course Content

The course starts with foundations of cryptographic techniques including symmetric ciphers, hash functions, public key encryption and digital signatures. Building on these foundations, more complex security protocols are studied. Especially secure voting is discussed as a complex security application for which even the definition of security is non-trivial. Basic models and methods from computer security are taught, including the Bell LaPadula model for access control.

All theoretical topics are enriched with case studies which show the limits of theoretical modeling and help building the mindset needed for successful work in the area of IT security.

Literature

- Ross Anderson: Security Engineering Second Edition, Wiley, 2008
- Jonathan Katz, Yehuda Lindell: Introduction to Modern Cryptography: Principles and Protocols, Chapman & Hall, 2007

Prerequisites for participation in course

Participants should have basic knowledge of higher math and linear algebra.

Modality of Exam

See 5.5

5.5.5 Hands-on Training: Platooning

Course Name

Hands-on Training: Platooning

Semester	Module Type	Allocated to the following Module	Lecturer
2	Elective	ADAS: Components and Technology of ADAS	Prof. Dr.-Ing. Eric Sax
Recurrence	**Mode of Teaching**	**Workload**	**Credit Points for Course**
Each summer semester	Dozent	Total 36h, hereof 15h contact hours, 21h homework and self-studies	1,2

Overall Course Objectives

The course objective is to get an idea of the practical realization of assistant functions.

Learning Targets
Participants ▪ work in groups on a case study (platoon) in order to cut through the analysis and draft process of electronic systems. ▪ Integrate components and functions of autonomous driving ▪ are able to apply methods and tools of model based analysis and draft and inspection procedure of hard- and software
Course Content
Participants complete a final design project as part of a multi-student team. All teams present their project in a verbal presentation to peers, faculty and industry audiences. They define requirements, estimate tasks and resources, engineer design implementations, validate solutions, idea to system perspective, mission analysis, functional analysis, system concept, functional and non-functional requirements specification, project management plan, system design, system analysis, design reviews, risk assessment, safety and security. The prototype to develop is the control of a platoon of a one-axle vehicles, based on case study in EM1. In the end the participants will integrate all the SW to control the system and even ride that vehicle autonomously behind a lead vehicle.
Literature
▪ Automotive Software Engineering (Schäuffele/Zurawka) ▪ Test Process Improvement (Koomen/Pohl) ▪ Project manager (Schelle et al.)
Prerequisites for participation in course
Requisites: “Software and Systems Engineering”; User Requirements for System under Development
Modality of Exam
See 5.5

5.6 E-Mobility: Components and Technology

Module Name			
E-Mobility: Components and Technology			
Semester	Subject	Module Supervisor	Credit Points for Module
2	Engineering	Prof. Dr.-Ing. Martin Doppelbauer	6

Module Content

The electric power train, i.e. the mechatronic integration of energy storage, power and signal electronics, drive control and electric motor, is the most innovative and important new part of hybrid and full electric vehicles compared to conventional combustion engine cars.

High-speed electric motors have become more and more powerful in recent years with new technologies like rare earth magnets and field weakening operation. The power-to-weight ratio of modern traction motors is more than a magnitude better compared to industrial electrical machines.

Power electronics is now capable of higher switching frequencies to reduce losses and audible sound. Sophisticated control algorithms further improve motor performance.

New and highly sophisticated power-split drive train topologies have been proposed and are being brought into series production.

Storage systems for electric energy are critical for the success of advanced car technologies. Lithium-ion batteries are improved and developed at high speed. Alternative energy sources, in particular fuel cells, achieve a degree of technical maturity that makes serial production possible in the foreseeable future.

Engineering module 4 focuses in detail on the technical components of electric and hybrid drive trains, namely the electric machine, power electronics (both hard- and control software), gearboxes, driving resistances and energy consumption and energy storage systems (batteries and fuel cells).

Learning Results (LR)

LR-1: Thorough understanding of different drive train topologies.

LR-2: Knowledge of the fundamentals of electric vehicle traction drives and power electronics.

LR-3: Methodical skills in the analysis and design of electrical drive systems.

LR-4: Knowledge of the fundamentals of mobile electric energy storage systems, namely lithium-ion batteries, fuel cells and H2-storage tanks.

LR-5: Methodical skills in the analysis of electric storage systems.

Workload

Total 180h, hereof 75h contact hours, 105h homework and self-studies (hereof 65 during module, 40 in preparation of module)

Controls of Success In EM 4 (5.6)	Modality of Examination	Performance and Duration of Examination	Prerequisites for Exam-participation	Examination Period	Graded

5.6.1 Electric Drive Trains 5.6.2 Power Electronics	Oral examination	Approx. 30 minutes per candidate	None	At the end of the course week	Yes
5.6.3 Energy Conversion 5.6.4 Energy Output	Oral examination	Approx. 30 minutes per candidate	None	At the end of the course week	Yes
5.6.5 Energy Storage: Batteries and Fuel Cells, H2-Storage	Oral examination	Approx. 20 minutes per candidate	None	At the end of the course week	Yes
Grading: The module grade shall be considered proportionally to the credits assigned to the courses.					

5.6.1 Electric Drive Trains

Course Name			
Electric Drive Trains			
Semester	Module Type	Allocated to the following Module	Lecturer
2	Elective	E-Mobility: Components and Technology	Prof. Dr.-Ing. Martin Doppelbauer
Recurrence	Mode of Teaching	Workload	Credit Points for Course
Each summer semester	Dozent	Total 36h, hereof 15h contact hours, 21h homework and self-studies	1,2
Overall Course Objectives			
The course provides an overview of the requirements for electric drives in hybrid and full electric vehicles. Starting with the requirements arising from the vehicle design, the currently available motor variants are presented in detail. The students learn how to assess motor design with regard to energy efficiency and performance. They get detailed knowledge about design criteria and design rules and are able to perform basic calculations of motor performance.			
Learning Targets			
Participants understand the functions of electric and hybrid drive trains for electric vehicles. They have an understanding of the different types of electric motors and their particular characteristics when used as traction drives. Participants have detailed knowledge on the working principles of motors, namely the magnetic and electric equivalent circuits. They are able to evaluate basic motor designs and are familiar with the properties of hard and soft magnetic materials.			
Course Content			
▪ Overview on hybrid and full electric drive trains (structure, requirements on motors) ▪ Fundamentals of rotating electric machines (operating principle, magnetic and electric circuits, gearbox integrated			

motors, traction motors, usage of gearboxes, torque-speed-characteristics, fundamental speed range, field weakening speed range, soft magnetic materials, hard magnetic materials, conductor materials, cooling, power density) ▪ Synchronous machines (operating principles, d-q-axis transformation, equivalent circuit, operation modes, phasor diagram, current plane, operating limits, PM- and salient pole machine design, rotor design) ▪ Induction machines (operating principles, equivalent circuit, phasor diagram, operation modes) ▪ Special machine types (axial flux machine, transversal flux machine, switched reluctance machine)
Literature
None
Prerequisites for participation in course
Basic knowledge of electrical and magnetic circuits (Maxwell equations).
Modality of Exam
See 5.6

5.6.2 Power Electronics

Course Name			
Power Electronics			
Semester	Module Type	Allocated to the following Module	Lecturer
2	Elective	E-Mobility: Components and Technology	Prof. Dr.-Ing. Marc Hiller
Recurrence	Mode of Teaching	Workload	Credit Points for Course
Each summer semester	Lectures and exercises	Total 36h, hereof 15h contact hours, 21h homework and self-studies	1,2
Overall Course Objectives			
The lecture shows the fundamental principle of power electronics, which consists in switching voltages with nearly ideal transistors and integrating them to currents by inductors which then additionally can be integrated by capacitors to other voltages. Frequency converters additionally convert the frequency.			
Learning Targets			
Participants ▪ get to know how choppers and inverters work. ▪ gain knowledge of the required components and their dimensioning. ▪ gain knowledge of chargers for electric cars.			

▪ understand how inverters work for the engine of electric cars. ▪ recognize the possibilities and advantages of a bidirectional network integration of electric vehicles and their beneficial combination with renewable energies.
Course Content
The application of power electronics is growing very fast. Especially in the areas of renewable power generation, power saving and E-Mobility, power electronics is a key technology. Power electronics circuits are used to convert electricity to different voltages or currents. The conversion efficiencies can be up to 99%, depending on the application. The course gives an overview on the principles of power electronics, the basic power electronics circuits and different applications.
Literature
▪ Fang Lin Luo und Hong Ye: Power Electronics: Advanced Conversion Technologies, January 2010 ▪ Daniel Hart: Power Electronics, January 2010 ▪ Andrzej M. Trzynadlowski: Introduction to Modern Power Electronics, Second Edition, April 2010
Prerequisites for participation in course
Basics in electrical engineering, basics of active and passive components (transistors, inductors, capacitors)
Modality of Exam
See 5.6

5.6.3 Energy Conversion

Course Name			
Energy Conversion			
Semester	Module Type	Allocated to the following Module	Lecturer
2	Elective	E-Mobility: Components and Technology	Dipl.-Ing. Sascha Ott
Recurrence	Mode of Teaching	Workload	Credit Points for Course
Each summer semester	Lectures and project work	Total 18h, hereof 7,5h contact hours, 10,5h homework and self-studies	0,6
Overall Course Objectives			
▪ Understanding of the complexity of energy conversion systems. ▪ Understanding the interactions between energy conversion and others inside a mobile system. ▪ Knowing methods to identify optimal solutions. ▪ Be able to apply basic methods of layout and dimensioning of powertrain systems.			

- Be able to apply basic methods of objective rating of different powertrain solution.
- Knowing the specific needs for the development of powertrain systems, using the broader approach of energy conversion.

This course is strongly related to all other courses in the module EM1.

Learning Targets

Participants

- gain knowledge of the physical basics of innovative powertrain technologies.
- understand goal setting methods for developing new drive systems.
- gain insight into the complexity of energy conversion.
- understand the interactions between energy conversions and other systems within a vehicle.
- overview the specific requirements of drive systems.

Course Content

This course provides the participants with fundamental knowledge in conventional and new powertrain systems. The course starts with an overview of typical concepts for the energy conversion inside different powertrain systems. Using a new taxonomy, based on the physical effects of energy conversion, the solution space for innovative, methodological derived powertrain solutions will increase for the participants of this course. Therefore, the different nowadays and future available powertrain technologies are analyzed; focused on the following:

- Technical, ecological and economical rating
- Customer acceptability

Due to the systematic view on the powertrain technologies, it will be able to understand the interactions between the different technical parts of the energy conversion systems. Based on that, optimal powertrain technologies for different settings (environment, traffic, customer user profile, etc.) can be identified by systematic rating or developed using the learned methodology.

Literature

Is provided during the lecture

Prerequisites for participation in course

No prerequisites required.

Modality of Exam

See 5.6

5.6.4 Energy Output

Course Name

Energy Output

Semester	Module Type	Allocated to the following Module	Lecturers
2	Elective	E-Mobility: Components and Technology	Dr.-Ing. Michael Frey Dipl.-Ing. Hans-Joachim Unrau
Recurrence	**Mode of Teaching**	**Workload**	**Credit Points for Course**
Each summer semester	Lectures and exercises	Total 18h, hereof 7,5h contact hours, 10,5h homework and self-studies	0,6

Overall Course Objectives

Understanding of the mechanisms of force transmission from wheel to road and the occurring energy loss.

Learning Targets

Participants

- gain knowledge of the main parameters of force transmission and the effects on the vehicle safety.
- analyze the energy turnover from the generation to the street.

Course Content

The course gives the students an insight into the transmission of power from the wheel to the road. As the tire is the only interconnection from the vehicle to the track, the course focuses on the tire and its properties. The course covers the following topics:

- Introduction: tire tasks and requirements; tire construction
- Rubber properties: viscoelastic behavior; adhesion and hysteresis friction
- Tire forces and moments: definitions; longitudinal and lateral forces, combined stress; parameter influences: camber angle, inflation pressure, tread height, etc.; influence of track surface
- Energy loss: rolling loss; influencing parameters; power loss during transmission of driving or braking forces

Literature

- Braes, H.-H.; Seiffert, U.: Handbook Of Automotive Engineering, SAE International, 2005
- Crolla, D.: Automotive Engineering: Powertrain, Chassis System and Vehicle Body

  Butterworth-Heinemann, 2009
- Pacejka, H. B.: Tyre and Vehicles Dynamics, Elsevier Ltd., Oxford, UK 2006

Prerequisites for participation in course

Basics in automotive engineering.

Modality of Exam

See 5.6

5.6.5 Energy Storage: Batteries and Fuel Cells, H2-Storage

Course Name			
Energy Storage: Batteries and Fuel Cells, H2-Storage			
Semester	Module Type	Allocated to the following Module	Lecturers
2	Elective	E-Mobility: Components and Technology	Prof. Helmut Ehrenberg Prof. Dr. Maximilian Fichtner Dr. Frieder Scheiba
Recurrence	Mode of Teaching	Workload	Credit Points for Course
Each summer semester	Lectures	Total 72h, hereof 30h contact hours, 42h homework and self-studies	2,4

Overall Course Objectives

The lectures related to Batteries, Fuel Cells and H_2 Energy Storage will give an overall picture of the technologies currently used in innovative environmental and energy conversion applications. The lecture course related to these two topics is divided in three parts. Firstly, fundamentals of thermodynamics and electrochemistry are presented and the losses associated with transport and electrochemical reaction processes during energy conversion are treated. The second part covers the structure and operating principles of fuel cells as well as the most important approaches in electrical characterization and modeling. Applications in mobile and stationary systems in the mobility and in the energy sector are discussed (low-temperature fuel cells as energy source in electric vehicles, high-temperature fuel cells in the decentralized power supply). The last section deals with electrochemical energy storage, the focus being on high-energy batteries for electro traction (e.g. lithium-ion battery, sodium-nickel chloride battery). Current developments leading to an enhancement of power densities are presented, as well as the electrical characterization and modeling of batteries.

Learning Targets

Participants

- gain competency and understanding for the applied methods for hydrogen and energy storage as well as energy conversion technologies.
- understand the necessity of the primary energy consumption, the availability of energy resources and the necessity to develop new storage systems.
- learn the technologies of energy storage methods of thermal, chemical, electrochemical, mechanic and miscellaneous types.
- are enabled to select an appropriate energy storage method according to the usage.

Course Content

Reliable and affordable energy storage is a prerequisite for using renewable energy in remote locations, for integration into the energy system and the development in a future decentralized energy supply system. Energy storage therefore has a pivotal role to play in the effort to combine a future, sustainable energy supply with the standard of technical services and products that we are accustomed to and need.

In future energy storage is needed to store electricity, heat and cold, which is produced at times of low demand and low generation cost and from intermittent energy sources such as wind and solar power. It is released at times of high demand and

high generation cost or when there is no more generation capacity available.

The lecture will give an overview on the following topics:

- Development of the primary energy consumption and the availability of energy resources.
- The increasing need to store energy.
- Energy Storage Methods: Thermal, chemical, electrochemical, mechanical and other.
- Selection of the appropriate storage method depending on the application.
- Presentation and discussion of application examples.

The need for new and sustainable energy technologies is particularly urgent in the transport sector, where energy demands keep growing and give rise to significant global and local pollution. Hydrogen is expected to play a key role in this development.

Hydrogen storage is regarded as one of the most critical issues, which has to be solved before a technically and economically viable hydrogen economy can be established. In fact, without effective storage systems, a hydrogen economy will be difficult to achieve. One of the most challenging applications in this field is hydrogen storage for mobile applications. Various scientific, technological and safety issues have to be considered which will be covered by the following topics of the lecture, with an emphasis on metal hydrides:

- Properties of hydrogen
- Binding principles for hydrogen
- Methods for hydrogen storage: Physical storage liquid and compressed hydrogen
- Solid hydrogen storage by physisorption and chemisorption
- Chemical storage
- Metal hydrides: types, thermodynamics and kinetics
- Complex hydrides
- Solid State Reaction Systems
- Hydrides at the nanoscale
- Hydrogen Safety
- Background; Incidents with hydrogen
- General considerations
- Safe handling of hydrogen storage materials
- Safety of metallic hydrides
- Safety of complex hydrides

Literature

- Huggins R. A.: „Advanced Batteries", Springer, 2009.
- Linden D., Reddy T. B.: „Handbook of Batteries", MCGRAW-HILL PROFESSIONAL (3rd Edition), 2002.

Prerequisites for participation in course

Basic understanding of electrochemistry and thermodynamics.

Modality of Exam

See 5.6

5.7 Systems Integration and Validation

Module Name			
Systems Integration and Validation			
Semester	Subject	Module Supervisor	Credit Points for Module
3	Engineering	Prof. Dr.-Ing. Eric Sax	6

Module Content

Implementation and integration leads to testing the overall system according to the early requirements. During the overall process of engineering, testing has been prepared and done in order to check the maturity level. In simulations and prototyping environments quality assurance has been executed. At the end of those phases for the first time the real system can be tested to check finally the user requirements in a Hardware-in-the-Loop (HiL) environment or even in real test scenarios. Several testing techniques beyond classical HiL are introduced and finally validation in real environments especially of self-learning functionality is part of this module. A case study will cover safety and security aspects.

All these topics are discussed considering the constraints of distributed development all around the world. In addition the demand of ongoing updates during usage - stationary or over the air – will after start of production rely on a complex release- and configuration management which is spread all over the world.

Learning Results (LR)

LR-1: Understanding of the total quality management approach in the product development process of electronic systems.

LR-2: Knowledge of the optimization of hardware and software architectures for testing during development.

LR-3: Assessment and optimization of the analysis and design process of electronic systems.

LR-4: Aspects of safety and security are well known and can be integrated into overall testing techniques.

LR-5: Ability to apply methods and tools for a distributed development process and familiarity with a worldwide release and configuration management.

Workload

Total 180h, hereof 75h contact hours, 105h homework and self-studies (hereof 65 during module, 40 in preparation of module)

Controls of Success In EM 5 (5.7)	Modality of Examination	Performance and Duration of Examination	Prerequisites for Exam-participation	Examination Period	Graded
5.7.1 Quality Assurance and Cost of QA of Electronic Systems	Written examination	120 minutes	None	At the end of the module	Yes
5.7.2 Testing Automotive Systems (XiL, Virtual Testing,…)					

5.7.4 Release-, Configuration- and Update-Management of Self-Learning Functionality			None		
5.7.3 Case Study in Testing Automotive Systems	Study Achievement	None	Participation in Case Study	-	No
Grading: The module grade shall be considered proportionally to the credits assigned to the courses.					

5.7.1 Quality Assurance and Cost of QA of Electronic Systems

Course Name			
Quality Assurance and Cost of Electronic Systems			
Semester	Module Type	Allocated to the following Module	Lecturer
3	Compulsory (course is assigned to student by examination board)	Systems Integration and Validation	Prof. Dr.-Ing. Martin Heine
Recurrence	Mode of Teaching	Workload	Credit Points for Course
Each winter semester	Lectures	Total 54h, hereof 22,5h contact hours, 31,5h homework and self-studies	1,8
Overall Course Objectives			
Master the state-of-the-art in design for system dependability, manufacturability and cost; apply measures to improve component and system quality; find optimum for system quality under time to market, reliability and cost constraints. Master the use of statistical data.			
Learning Targets			
Participants learn and adapt methodologies how to improve electronics system architectures for quality and manufacturability under time and performance constraints, for application to current and future technologies; capable to interpret and determine reliability and statistical data, understand cost issues in quality assurance for electronics components and systems.			
Course Content			
The course targets methods and rules for quality assurance management, reliability and cost issues for quality assurance of complex electronics systems. Emphasis will be placed on teaching and understanding feasible problem and solution strategies with regard to time-, cost- and performance optimization for quality assurance and reliability of electronics hardware systems. Use of statistical methods in process control, prototype tests, quality assurance tests and characterization tests, as well as the resulting cost figures, will also be discussed.			

Specific course topics include electronics hardware IC and PCB design with respect to reliability, manufacturability, quality assurance and cost; methods to improve yield; setting up procedures for prototype tests, production tests and quality assurance tests, obtaining reliability data for hardware components, determining failure rate and system mean time to failure, mean time to repair, and system dependability; performing statistical process control, calculating fixed and variable costs for electronic products.
Literature
Birolini, Alessandro: “Reliability Engineering, Theory and Practice”, Springer Verlag Berlin Heidelberg
Prerequisites for participation in course
No prerequisites required.
Modality of Exam
See 5.7

5.7.2 Testing Automotive Systems (XiL, Virtual Testing…)

Course Name			
Testing Automotive Systems (XiL, Virtual Testing…)			
Semester	Module Type	Allocated to the following Module	Lecturer
3	Compulsory (course is assigned to student by examination board)	Systems Integration and Validation	Dr. Christian Müller
Recurrence	Mode of Teaching	Workload	Credit Points for Course
Each winter semester	Lectures and exercises	Total 54h, hereof 22,5h contact hours, 31,5h homework and self-studies	1,8

Overall Course Objectives
The course objective is to introduce a structured testing approach based on an efficient combination of different test phases and different test technologies.
Learning Targets
Participants ▪ are able to analyze and structure test needs concerning the test object, the test reference and the test phases. ▪ get an overview of state of the art test technologies for automotive EE systems. ▪ are able to sketch the guidelines for new test projects and optimize existing test projects.
Course Content

Testing of embedded systems gives transparency to the maturity level of a product. Consequently, it is the essential basis for quality improvements and final approvals for a release of a product. Test methods and technology have to be continually adapted to any new challenges coming e.g. from new technologies, new requirements concerning safety regulations or new applications such as autonomous driving. Since testing usually happens in late phases within the development process, the requirements in regards to cost, time and quality are particularly important. No requirement without test(s) and no test without requirement(s) is the maxime.

The course shows different aspects of efficient embedded system testing with a specific focus on the automotive industry: Choosing and defining the right test process as part of the overall development process (s. other lectures) is the fundamental approach. For an overall boost in efficiency all test phases along all integration steps have to be synchronized and linked while taking into account the respective test topics at the right time and using the fitting test technology. The necessity, the advantages but also the limitations of test automation will be discussed.

Theory is combined with practical examples based on today's challenges in the automotive EE systems like ADAS or alternative drive trains.

Literature

- Automotive Software Engineering (Schäuffele/Zurawka)
- Test Process Improvement (Koomen/Pohl)
- Automatisiertes Testen Eingebetteter Systeme in der Automobilindustrie (Sax et al.)
- Handbuch Fahrerassistenzsysteme (Winner, H., Hakuli, S., Lotz, F., Singer, C. (Hrsg.)

Prerequisites for participation in course

Embedded Software and Systems Engineering

Modality of Exam

See 5.7

5.7.3 Case Study in Testing Automotive Systems

Course Name

Case Study in Testing Automotive Systems

Semester	Module Type	Allocated to the following Module	Lecturer
3	Compulsory (course is assigned to student by examination board)	Systems Integration and Validation	Dipl.-Ing. Hannes Stoll
Recurrence	**Mode of Teaching**	**Workload**	**Credit Points for Course**
Each winter semester	Lectures and case studies	Total 36h, hereof 15h contact hours, 21h homework and self-studies	1,2

Overall Course Objectives

The course objective is to get an expert view into today's methods on testing automotive systems. Using the state-of-the-art computer-aided-engineering tools will familiarize the students with the latest techniques.
Learning Targets
Participants ▪ work on independent case studies in small working groups and get used to teamwork ▪ are able to apply methods and tools of hardware in the loop testing ▪ are able to identify bugs systematically within a given period of time.
Course Content
In this case study an automotive system will be tested with latest test equipment in the laboratory. Hardware-in-the-Loop will be used for that semi- and fully automated approach for electronic system testing. Participants complete a final test project as part of a multi-student team. All teams present their project in a verbal presentation to peers, faculty and industry audiences. The structured analysis of the requirements of real-time systems, systematic derivation of test cases and pass/fail criteria will lead to a professional test operation. Test coverage, automation and reporting techniques will furthermore be exercised. An automatic bus door will be the system-under-test.
Literature
▪ Automotive Software Engineering (Schäuffele/Zurawka) ▪ Test Process Improvement (Koomen/Pohl) ▪ Testing embedded software (Bart/Notenboom) ▪ Project manager (Schelle et al.)
Prerequisites for participation in course
Lectures in "Systems Engineering", "Case Study in Systems Engineering", "Testing Embedded Systems", Specification of the System under Test
Modality of Exam
See 5.7

5.7.4 Release-, Configuration- and Update-Management of Self-Learning Functionality

Course Name			
Release-, Configuration- and Update-Management of Self-Learning Functionality			
Semester	Module Type	Allocated to the following Module	Lecturer

3	Compulsory (course is assigned to student by examination board)	Systems Integration and Validation	Prof. Dr.-Ing. Eric Sax
Recurrence	Mode of Teaching	Workload	Credit Points for Course
Each winter semester	Lectures and case study	Total 36h, hereof 15h contact hours, 21h homework and self-studies	1,2

Overall Course Objectives

The course objective is to introduce a structured testing approach for functionality that is learned autonomously. This is done once before start of production and then continuously during lifetime with each update on complex release and configuration structures of products in use.

Learning Targets

Participants

- are able to analyze and structure tests needed to identify a maturity level of the system under test.
- learn how to apply data analytics to identify abnormal behavior.
- are able to set up test scenarios for complex self-learned functionality.
- Know the differences of releases, variants and configurations
- are able to define and choose the right update technique

Course Content

Especially for highly automated driver assistance functions self-learning is a major issue. To the contrary to in advance specified functions now there is not a defined reference for passing the tests. What is good or good enough? Maturity levels get more and more important from first prototyping until late licensing by the authorities. Updating due to self-learning aspects of complete car fleets demand no ways of over the air communication and security testing. New means in the test field but as well in the laboratory are introduced. Furthermore, the idea is to get an expert view into the challenges of software and component release management over lifetime. Update strategies are introduced; the demands of remote techniques including safety and security aspects are explained.

Literature

- Automotive Software Engineering (Schäuffele/Zurawka)
- Test Process Improvement (Koomen/Pohl)
- Automatisiertes Testen Eingebetteter Systeme in der Automobilindustrie (Sax et al.)
- Handbuch Fahrerassistenzsysteme (Winner, H., Hakuli, S., Lotz, F., Singer, C. (Hrsg.)

Prerequisites for participation in course

Lectures in **"**Systems Engineering", "Case Study in Systems Engineering", "Testing Embedded Systems", Specification of the System under Test

Modality of Exam

See 5.7

6 Master Thesis Mobility Systems Engineering and Management

The Master Thesis can be performed either as a research project in one of the institutes at the university or outside the university in cooperation with the participant's company. In the latter case it should be performed under the supervision of an advising faculty member from the HECTOR School.

The following table (Tab. 6-1) summarizes the Master Thesis scope and process:

Content	The Master Thesis should contain the following aspects: ▪ description of the problem ▪ review of the relevant literature (state of the art) ▪ definition, selection and description of suitable approaches ▪ execution of the necessary work schedule (experiments, statistical analyses) ▪ derivation of a conclusion ▪ discussion of validity, scope and verification
Learning Targets/ Skills	Participants demonstrate the skills to independently solve a scientific problem adapting methods and models acquired during participation in the modules 1-10.
Pre-Requisites	Successful completion of 80% of the modules and exams.
Workload	The Master Thesis is to be completed within a period of 9 months. Start of the Master Thesis is the 1st day of the following month after the 8th HECTOR School module.
Master Thesis Operations	1. Orientation Phase: Until module 6 the participants are asked to search for a project within their professional environment. Along with this, they are also asked to search for a first supervisor within the lecturers of the HECTOR School. 2. Registration Phase: The participants are asked to hand in the official Master Thesis application form with an outline of the Master Thesis topic and signed by the chosen first supervisor to the student office of the HECTOR School until the end of module 8. The participant then receives the approval by the study regulations committee. 3. Project Phase: The project phase starts with the 1st of the following month after the 8th HECTOR School module. During the project phase the participants are asked to follow a milestone plan, which is agreed on with their supervisor. The participants regularly report about their progress to the HECTOR School. Before the final submission, the students will hold official colloquia, where they are asked to present the contents of their Master Thesis in a 20 minutes colloquium using modern media. The colloquia dates are usually set around 4 weeks before the official submission date. 4. Submission Phase: The participant is asked to hand in two paper copies and a digital version on CD or data stick to the student office by the announced completion date. Templates and style formats will be communicated by the HECTOR School.

Tab. 6-1 Master Thesis scope and process

Further information on the Master Thesis regulations can be seen in the General Study and Examination Regulations, § 11 (see also Chap. 9.4).

7 Karlsruhe Institute of Technology (KIT)

On October 01, 2009, the Karlsruhe Institute of Technology (KIT) was founded by a merger of Forschungszentrum Karlsruhe and Universität Karlsruhe. The basis was the KIT Merger Act that was adopted unanimously by the Baden-Württemberg state parliament in July 2009. KIT bundles the missions of both precursory institutions: A university of the state of Baden-Wuerttemberg with teaching and research tasks and a large-scale research institution of the Helmholtz Association conducting program-oriented provident research on behalf of the Federal Republic of Germany. Within these missions, KIT is operating along the three strategic fields of action of research, teaching, and innovation.

With roundabout 9450 employees and an annual budget of about EUR 850 million, one of the largest research and teaching institutions nationwide is established in Karlsruhe. It has the potential to assume a top position worldwide in selected fields of research. The objective: KIT will become an institution of top research and excellent scientific education as well as a prominent location of academic life, life-long learning, comprehensive advanced training, unrestricted exchange of know-how, and sustainable innovation culture.

7.1 Department of Mechanical Engineering

Production Technology: Taking an integrated approach

The holistic treatment of products and production in an international environment is central to industrial engineering research projects at Karlsruhe; included in this is not only manufacturing itself, but also operation, maintenance and recycling. The opening of national borders for industries results in the necessity to reduce development times and in turn increase the application of technical models and computational simulations.

Research at Karlsruhe in production focuses on taking an integrated approach to the product and the production within an international context. It is not restricted to the process of production alone, but also includes aspects such as plant operation, maintenance and recycling. Another aspect is the increasing pressure to intensify automation. Research and teaching at the Department’s production-technology oriented institutes cover almost every phase of the product life cycle. Research includes issues such as product planning, design, production planning, manufacturing and assembly, quality management, material flow technology and logistics as well as industrial management and ergonomics.

Product Development and Design: The creative element

Product Development and Design have the goal of examining and developing a theoretical basis for methodical development processes including the respective computing systems (CAD/CAM). Taking traditional design methods as a starting point, researchers use an integrated approach to accompany and systematically manage the entire product development and production process. Complex product development and production tasks are solved in close cooperation with industry. In doing so the focus is on the entire development chain – from environmentally compatible and strategic product planning brainstorming all the way to creating complete three dimensional CAD designs is focused on. Simulations and prototype construction are also part of the process. Other research areas include:

- Energy and environment – developing sustainable technology
- Material Technology – enabling innovative engineering
- Microsystem technology- large impact from small devices
- Mechatronics – a symbiosis of two technological worlds
- Vehicle and powertrain technology – the motors of a mobile society
- Theoretical basics – the foundations of engineering

7.2 Department of Economics and Business Engineering

Research and teaching in the Department of Economics and Business Engineering at Karlsruhe is distinguished by interdisciplinary networked tasks and a focus on current developments. The faculty is the largest training center for graduate industrial engineers in Germany.

The interdisciplinary course in industrial engineering with business studies has characteristics that are typical for Karlsruhe Institute of Technology (KIT): it is geared towards quantitative problems and is therefore strongly method-orientated; it also includes applied computer science. Working in an interdisciplinary network, perhaps taking both economic and technical aspects into account at the same time, is essential for the design, manufacture and marketing of products.

Interdisciplinary research

Despite the large number of resources devoted to teaching at the institutes, research is still very much a priority. The interdisciplinary Research Training Group “Market Engineering” recently founded bridges the gap between education and research. The program is devoted to designing institutions, services, systems and social models for electronic markets while taking into account all of the economic, technology-based and legal aspects.

The main fields of research include:

- Finance and capital market research
- Marketing and market research
- Mapping work processes using computer science
- Information management
- Production and materials flow management
- Ergonomics
- Sustainable construction
- Traffic prediction and transport network planning
- System dynamics and innovation
- Optimization, resource management and risk management
- Actuarial science and applied risk science
- Welfare economics
- Experimental economic research

7.3 Department of Computer Science

Without the use of computers hardly anything in our society would function. Whether in transportation, production, administration, health care or leisure, computers unobtrusively complete increasingly important tasks. As a result, information technology has become an extremely significant sector. The Universität Karlsruhe (TH) was the first German university to offer a full Diploma degree in computer science in 1972. Ever since then, the Department of Computer Science is considered a leader in the field and internationally ranked number one in all the major rankings and evaluations.

Research and education in computer science at the Karlsruhe Institute of Technology (KIT) is characterized by its breadth coupled with a strong focus on theoretical and practical aspects of computer science. The value that the faculty places on multi-disciplinary education is shown by the offer of business informatics degree program. Other fields of research include:

- The applications of computer science: computer-aided surgery
- Semi-humanoid robot systems
- Computers for everyday use

7.4 Department of Electrical Engineering and Information Technology

Its 15 institutes – including two interdepartmental research centers – and approximately 1500 students put the department in the very heart of engineering at the Karlsruhe Institute of Technology (KIT). By focusing on automation, energy, information and communication technology and electronic components and circuits, the faculty puts students in touch with all of the cutting-edge areas of electrical engineering and information technology.

The demand for components and systems for the fast transfer, storage, visualization and processing of information is steadily increasing. Hybrid and quantum components and molecular electronics result in completely new possibilities for future information processing and storage.

Microelectronic and nanoelectronic components also enable the so-called System on Chip (SoC): the integration of complete microelectronic systems onto a single silicon chip has become feasible through the rapid development of CMOS VLSI technology. This demands cost-effective technology, application specific hardware/software architectures and highly efficient design methods. Other research areas include:

- Mechatronics – new functions through interdisciplinary research
- Energy at the cross roads of ecology and economics
- Fuel cells: a technology for the future
- Wireless communication: effective planning of transmitter networks
- Systems engineering: personal health monitoring
- Aviation and aeronautics
- Microelectronics, nanoelectronics and optoelectronics

7.5 Department of Chemical Engineering

The Department of Chemical Engineering and Process Engineering at the KIT with 12 chairs at 6 institutes and about 1000 students is one of the world's largest in their field of study. Chemical Engineers have been educated successfully in Karlsruhe since 1928. The traditional courses chemical engineering and process engineering were complemented by the bioengineering program in 2001. All three courses have steadily increasing intake and graduate numbers.

Chemical engineering, process engineering and biological engineering are interdisciplinary engineering sciences connecting the fields of engineering, technical physics, mathematics, and chemistry. The focus of research and teaching at the faculty is in the three general themes material process technology, biotechnology and food technology, energy and environmental technology.

7.6 Department of Civil Engineering, Geo and Environmental Sciences

At the beginning of the foundation of the University of Karlsruhe stood the engineer Johann Gottfried Tulla. In 1807 he founded an Engineering School in order to educate employees for the administration of Highway Building and Hydraulic Engineering, which was organized by him. An architect joined this project: Friedrich Weinbrenner, his Building School arose from the Architectural Drawing School, which existed since 1787. The union of Tulla's Engineering School and Weinbrenner's Building School with the Academy of Machine Construction of Freiburg and a School of Forestry gave rise to the foundation of a Polytechnic School in 1807. It achieved academic quality and was called "technical academy". Tulla, the principal of the highway building and hydraulic administration of Baden County had already intensely prepared the project. In Paris short after Napoleon's coup d'état he had got to know the Polytechnic University of Ecole – the University, which at first gave its students a basic scientific education, before it specialized the prospective engineers in their future profession.

Today both the traditional acquiring of basic scientific knowledge and accomplishing of applied scientific work are regarded as equally important at the University Fridericiana, how the university is called since 1902. And Tulla's special field of activity - the regulation of the Rhein is still researched today. Since 2002 Geo- and Environmental Sciences and the Civil Engineering work together within this department. Thus the dovetail connection and interaction of building structures and their environment and the study of intervention/interference in the city and cultivated landscape are accommodated during the education and research.

8 Appendix

8.1 European Credit Transfer and Accumulation System

8.1.1 What is the ECTS (European Credit Transfer System)?

The European System for calculating, assessing and accumulating student performance is a system specifically designed for students. It is based on the workload that the student must complete in order to achieve the objectives of the program of study. These objectives are primarily defined in the form of learning outcomes and the competencies that are to be acquired in the course of study.

8.1.2 What are the primary aspects of ECTS?

The ECTS is based on the general understanding that the workload for a full-time student during an academic year corresponds to a total of 60 ECTS-credits. That means that the workload for a full-time student studying in Europe comprises 1500-1800 working hours per year in most cases. For our part-time program the workload consists of 90 ECTS for the whole program which is effectuated in approximately 1,5-2 academic years.

- The workload in ECTS consists of the time that a student requires to complete a variety of learning activities, such as attending lectures and seminars (contact hours), self-study, project work, exam preparation, etc.
- Credits are assigned to all components of a program of study (e.g. modules, courses, laboratories, final project, etc.) and indicate the workload of each component in relation to the total workload that would be required in one full year of study in the appropriate program of study.
- The learning results are a set of competencies, which indicate what the students should know, understand, and be able to do at the end of a short or long learning process. Credits in ECTS are awarded to students only after the course has been completed and a corresponding evaluation of the desired learning results has been made.
- The assessment of student performance is documented via the commonly-used grading system for each local/national region. It is good practice, especially in the case of credit transfers, to include an ECTS grade. The ECTS grading scale ranks students based on a statistical distribution. Thus, statistical data on student performance is a necessary prerequisite for applying the ECTS grading scheme. Successful students can obtain the following grades: A for the best 10%, B for the next 25%, C for the next 30%, D for the next 25%, E for the next 10%. Unsuccessful course performance receives a grade F. The transcript of records need not specify the number of failed attempts.

8.2 Quality Management

The faculty of the Hector School of Engineering and Management guarantee for the quality and continual improvement of the curriculum. A number of tools are used in order to ensure the high academic and pedagogic standards defined by their members.

8.2.1 Lecture note evaluation

- Form, volume and content of the lecture notes must comply with scope and number of teaching hours
- Each contribution of the individual lecturers is evaluated by reviewers from the same field

8.2.2 Course evaluation

After each module a written questionnaire is distributed to the participants on which they can evaluate the quality of the lectures. The main topics are:

- lecture content
- mathematical demands
- practical applicability
- interference/overlap with other lectures
- relationship/link to preceding lectures
- speed of material presentation
- extension of the lecture material
- usefulness/relevance of lecture notes
- audibility of lecturer
- blackboard, transparency structure
- preparation of lecturer
- presentation style and motivation
- willingness to answer questions

After each module the returned questionnaires are analyzed and published on the sharepoint of the HECTOR School and are discussed with lecturers and students.

8.3 Admissions Regulations

The official “Satzung für den Zugang zu dem weiterbildenden Masterstudiengang Mobility Systems Engineering and Management am Karlsruher Institut für Technologie” can be found here: https://www.sle.kit.edu/amtlicheBekanntmachungen2010-2019_8565.php

A translated version of the “Admission Regulations” can be found on the SharePoint of HECTOR School.

8.4 General Study and Examination Regulations

The official “Studien- und Prüfungsordnung des Karlsruher Instituts für Technologie (KIT) für den weiterbildenden Masterstudiengang Mobility Systems Engineering and Management” can be found here: https://www.sle.kit.edu/downloads/AmtlicheBekanntmachungen/2017_AB_056.pdf

A translated version of the “General Study and Examination Regulations” can be found on the SharePoint of HECTOR School.

8.5 Fees Regulations

The official “ Satzung des Karlsruher Instituts für Technologie (KIT) über die Studiengebühren für die weiterbildenden Masterstudiengänge Electronic Systems Engineering & Management, Energy Engineering & Management, Financial Engineering, Green Mobility Engineering, Management of Product Development, Production and Operations Management, Service Management & Engineering” can be found here: http://www.sle.kit.edu/amtlicheBekanntmachungen2013.php

A translated version of the “Fees Regulations” can be found on the SharePoint of HECTOR School.