Curriculum

General
The MAS programme is offered as a full-time programme and a part-time programme with the same number of EC's. The total programme covers 90 EC. The curriculum is built up on elements with focus on theory, application and skills, in relationship to the end-qualifications. That means that the student is offered a theoretical background on automotive technologies and specialised scientific knowledge in Advanced Automotive Engineering and, particularly, Intelligent Vehicles. This includes knowledge on macro-economics and societal trends as main drivers for automotive R&D. Theory is applied within an automotive context (automotive systems and components) with emphasis on the performance of the automotive end-products, and with reference to the (improvement of) automotive company processes. Not only the technical achievement but also the consequences for financial efficiency and cost-benefit relationships will be addressed in the MAS assignments and practical elements and minor/thesis projects.
In addition to lecturing, we distinguish within MAS:

- Team and individual assignments
- Experimental research and laboratory exercises
- Model development and simulation exercises
- Group cases and management games
- Minor project
- Major master thesis project

with most of these activities including literature survey, oral presentations and reporting. Students will obtain guidelines in presentation and reporting skills, and will be commented on these communication achievements for a majority of their presentation and reporting results. Design of these activities as well as the assessments will be such that the graduate will develop his skills to formulate a problem, to solve that in a step-by-step iterative approach and to draw conclusions, which are of value to and in communication with the (non-specialist) problem owner(s), see figure 1. The student will also practice his skills to analyse the problem at an abstract level and break it up into elements to understand their relationships and organisation (system analysis) and to interpret the individual element performance in terms of the total automotive system performance (synthesis). Non-technical skills will be addressed as well, including working in teams (multidisciplinary, with a global international focus), self management of the learning process, and research skills.

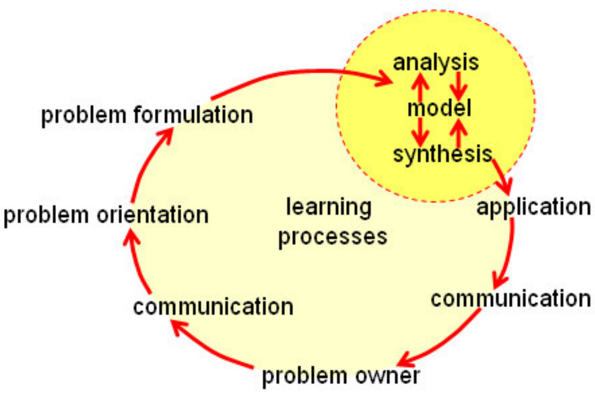


Figure 1 Skills and problem cycle

Being a master course, theory is important. Being a HBO master course, the graduate needs to have the proper skills to apply the theoretical background, according the MAS final qualifications. Therefore, all modules cover additional tasks beside theory, such as literature analysis, small assignment, take-home exercises, group assignments, guest lectures, etc. That means that all modules focus on theory, skills (practical activities, exercises, assignments) and applications (in lectures, through assignments, small projects). Developing skills and applications are much related. The difference is in the motivation, being either based on using theory or solving real-life problems. We have estimated the time spent on theory, deriving skills and applications for each module. See also figure 2.

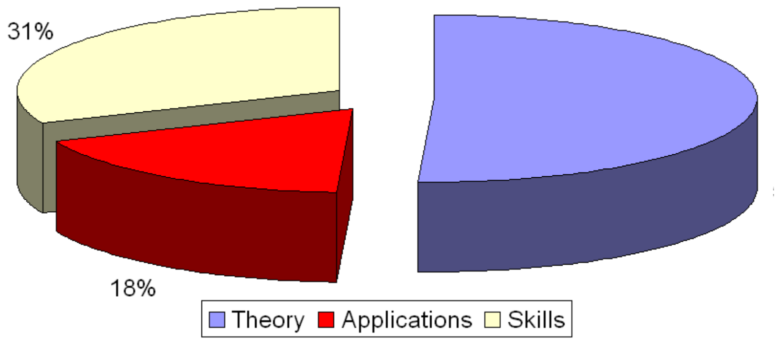


Figure 2 Time spent on theory, skills, projects, excluding minor and major thesis projects

The sequence of modules and learning processes is chosen such that students are gradually guided from a general automotive focus to more detailed topics and specializations. This guarantees that the theoretical and application background is improved during the course, such that the student is able to handle more difficult, complex and in-depth knowledge and skills in forthcoming modules.

The structure of the MAS course is indicated in figure 3. That means that we first start with introduction modules, aiming at establishing a general common understanding on automotive systems (IAS), and a shared minimum level in mathematics and mechanics (MM) with focus on application.

Next, the fundamentals are treated for combustion engines and thermodynamics, vehicle dynamics and vibrations, and driveline and transmissions. In parallel the student will practice general skills as part of these modules and through PMS (modelling and simulations).

Finally, the student will apply this fundamental knowledge and general skills in the minor project.

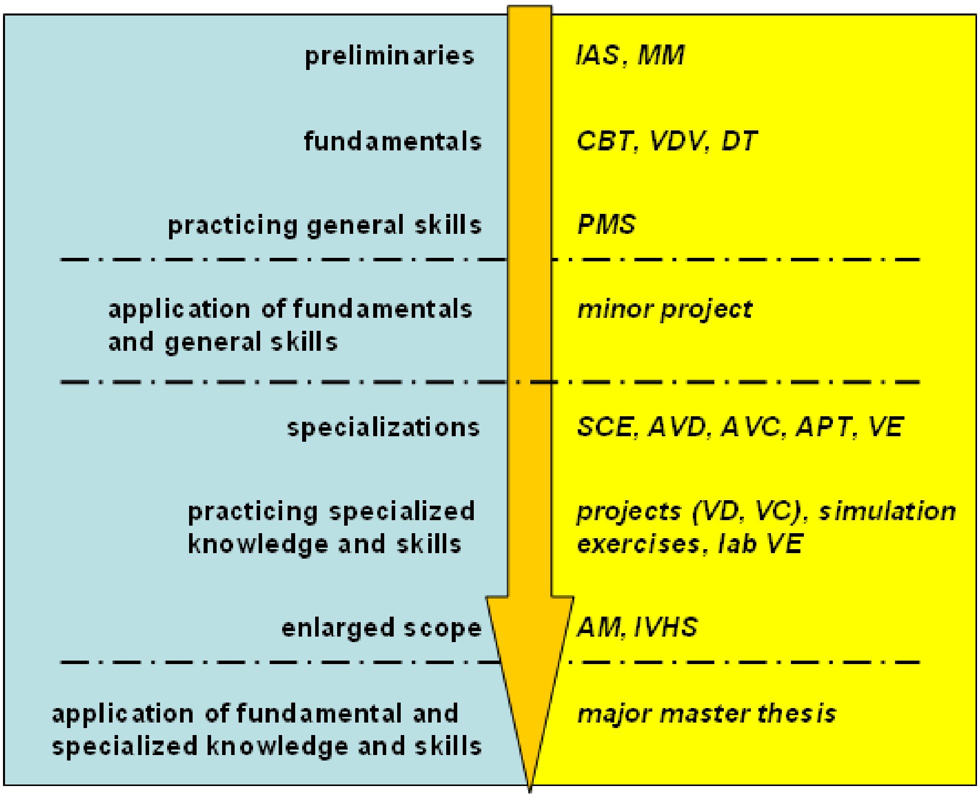


Figure 3 Vertical consistency of MAS programme

The next two periods (full-time programme) are then devoted to specialization, based on the learning experiences of the first two periods. AVD and AVC will built further on VDV, APT and VE will specialize on topics of CBT and DT. Also the practical aspects and self-study (projects, simulation exercises, and laboratory work) will focus more on the same specialized areas, and be directly linked to the theory of the various topics. In other words, the student is able to apply his theory in the practical work, and to reflect the outcome of his practical work in the theoretical parts of the modules.

In parallel to specialization, the scope of automotive research and engineering is enlarged, by addressing relationships with economical and societal demands, other disciplines, the automotive company environment in which engineering has its place, etc. This is true for all modules, but specifically in AM and IVHS The final proof of being able to apply both the fundamental and specialized knowledge and skills, takes place in the last semester(s) (master thesis).

We have schematically drawn the course programme in figure 4 for the full-time version, including the various modules, and period. Part-time students will take two years for the first two semester programme, including the minor project, practices, and lab activities.

Each half year consists of two separate periods, with a period lasting between 7 and 8 weeks, plus examination period. Modules are the combination of lectures, assignments, exercises, etc. for one specific topic. The scores for all parts of a module should be satisfactory (all pass).

Semester 1
The first half year includes a basic programme starting with an introduction in automotive systems. This introduction is meant to make the student familiar with the area of automotive engineering, to understand both the value of the separate R&D fields as well as their interrelated consequences on safety, environment and fuel efficiency. It also serves to achieve a common ground for the rest of the programme, and to work on possible deficiencies from prior (foreign) bachelor-level education. It includes assignments to practice the skills as mentioned above, and to motivate a group process and a "we're in this together" attitude among the students.
The other activities of the first half year deal with the three major automotive areas Vehicle

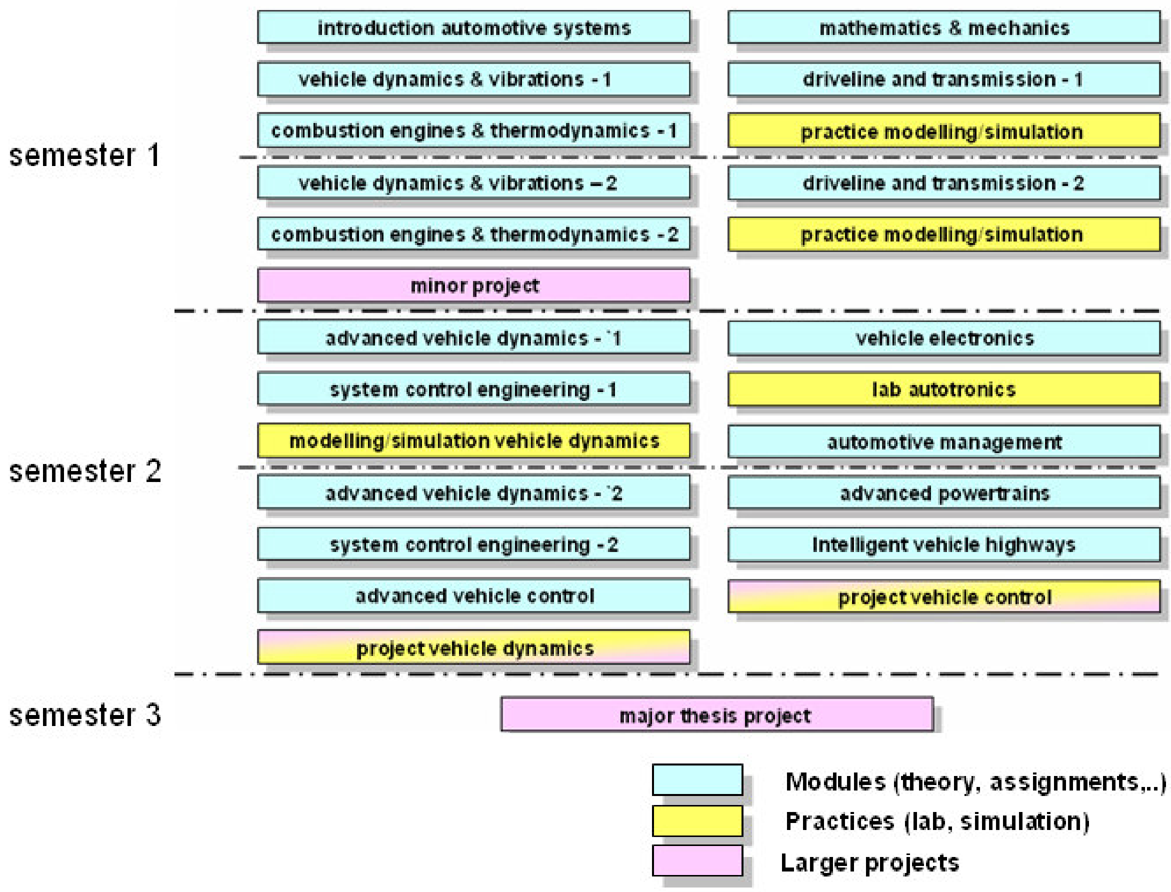


Figure 4 Curriculum MAS

Dynamics and Vibrations, Driveline and Transmission, and Combustion Engines and Thermodynamics. In addition, a course on mathematics and mechanics will be given with the same aim as the introductory course, i.e. to have a common basis for the master course in mathematics and mechanics. Automotive areas like vehicle dynamics and automotive control require specific knowledge of mathematical topics such as dynamical systems, numerical methods, linear multivariate analysis. These topics are linked to intelligent vehicle applications in the modelling and simulation practice (Matlab / SIMULINK / SIMMECHANICS). A minor project serves to challenge the students to apply their knowledge and skills on real-life problems, in correspondence with the end-qualifications (with a 'problem owner', within a realistic automotive environment, with several disciplines coming together, ….). The 9 EC minor project will be motivated by a real-life problem, with involvement of representatives of the professional field (acting as 'customer').

Semester 2
The second half year takes the knowledge one level higher, to specialize in those areas offering the knowledge and skills to improve vehicle performance, regarding the vehicle as an integration of intelligent (embedded) systems interfacing with the driver, other road users and infrastructure (in a very broad sense). The module on Automotive Management is specially designed to understand the dynamic world of automotive companies, their driving forces and policies, concepts, working processes as well as their business and technical solutions to survive in a competitive environment. Through lab-activities (often being a part of the larger projects), the projects on Advanced Vehicle Dynamics and Advanced Vehicle Control, and assignments as part of the various modules, the students will work on innovative developments such as fuel cells, driver and vehicle state estimation, active vehicle steering control, hardware-in-the-loop analysis of yaw control and brake control, etc.

Semester 3
The final master thesis project will demonstrate that the student is able to work at master level in the automotive professional working field. The final thesis is carried out on a problem, being motivated by the professional automotive field. This means, in most cases, that the master thesis is carried out at an automotive company or an automotive research centre.

The master programme is carried out in full-time and part-time with the same number of EC's. Part-time students will be working at an automotive company or service (R&D, consulting) organisation, or a related organisation. They will bring in their professional experience and motivation in the master. The planning of full-time and part-time lecturing is such that parts of the modules for full-time and part-time are combined. It stimulates the professional focus of both full-time and part-time students and it broadens their view by exchange of experiences.

Final Qualifications

The final qualifications for the Master of Automotive Systems (MAS) are defined as follows:

GENERAL

1 To work from an incentive to solve problems within a multidisciplinary and international context.

2 To manage (self management) and control effectively his/her own learning process and that of others (team members, project participants,…)

ROLE IN APPLIED RESEARCH

3 To analyse and interpret automotive technologies and technology development, in relationship with scientific, macro-economics and societal developments and trends.

4 To critically analyse the automotive problem through active communication with the problem owner, to translate this to problem formulation, feasible solution approaches and scientifically valid conclusions, to be communicated again to the (non-specialist) problem owner(s).

5 To systematically translate the automotive problem to a model at an abstract level, i.e. reducing it to its essentials in terms of model framework and problem requirements, and to (qualitatively and quantitatively) validate results against the real life situation and problem formulation.

6 Specialised scientific knowledge and skills (product, techniques, strategies for experiments, standards) in the broad field of Advanced Automotive Engineering and, particularly, Intelligent Vehicles including knowledge on the changing conditions, influences and uncertainties in research work.

DEVELOPMENT OF AUTOMOTIVE PRODUCTS

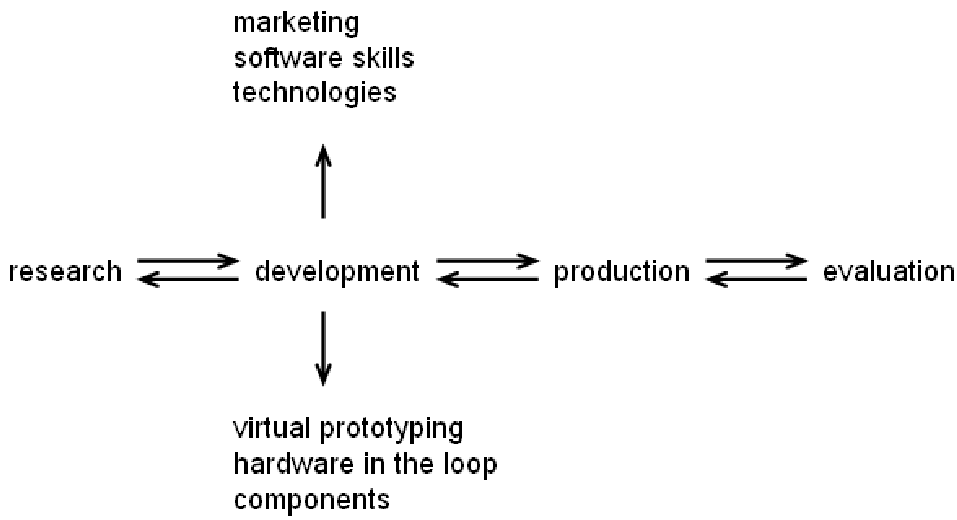
7 To derive a feasible (improved) end product from the selected solution approaches (see 4).

UNDERSTANDING OF AUTOMOTIVE PROCESSES AND EVALUATION

8 To advise on optimisation and improvement of automotive company processes within the context of automotive engineering, based on a thorough understanding of these interrelated processes including quality control principles.

9 Assessment of an automotive system/component as part of the automotive end product (the vehicle), i.e. in terms of vehicle performance

Starting point for the design of the Master of Automotive Systems are the company processes, indicated in the figure below.



The graduated engineer needs to have good skills and knowledge within the broad field of automotive technology including an understanding of the large variation of disciplines involved. This includes vehicle electronics, mechatronics, and software development, interfacing with driver and intelligent traffic and road environment.

The engineer also needs to understand the automotive company processes and recognise his own contribution within the total framework. This includes automotive management aspects such as production logistics and management, quality management, project management, cost control, marketing etc.

There is a practical result orientation with focus on the automotive end product. The engineers must be able to apply virtual and hybrid experimental engineering tools. His attitude should be oriented towards concurrent engineering and taking responsibility. The engineer must be able to communicate amongst different nationalities and disciplines.

Final qualifications versus the curriculum

The relationship between final qualifications and modules (with distinction in lectures, practices and larger projects) is indicated in table 1. There are two levels, where qualifications are clearly reflected in the modules and where modules contribute to a certain qualification. The didactical concept of the course is such that students are offered knowledge through lecturing (and self-study), combined with practicing the application of this knowledge in automotive context. Hence, a theoretical firm basis of the knowledge is gained first, and then transferred into active knowledge by practicing in real life applications.

• Module contributes to qualification
☑ Qualification reflected in Module/part of module

	Multidisciplinary, international context	Manage learning process	Scientific, macro-economics, societal trends	Problem cycle and commun-ication to problem owner	Abstract level model formulation	Specified scientific knowledge and skills	Feasible end-product	Improved automotive company proecesses	Assessment in terms of vehicle performance
Module:	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**
Introduction Automotive Systems	☑	☑	☑	☑	•	☑	•	☑	☑
Mathematics and Mechanics			•		•	☑			
Combustion and transmission	•		☑		•	☑	☑		☑
Vehicle dynamics and vibrations	•		☑		•	☑	☑		☑
Driveline and transmission	•				•	☑	•		•
Practice Modelling and Simulation		☑		•	☑	☑	•		•
Minor project	•	☑	•	☑	☑	☑	•	•	☑
Advanced Vehicle Dynamics	•		☑		•	☑	☑		☑
- modelling/simulation vehicle dynamics	•		•	•	☑	☑	☑		☑
- project vehicle dynamics	•	☑	•	☑	☑	☑	☑		☑
Vehicle Electronics	☑		☑		•	☑			
- lab autotronics	☑	☑	•		•	☑			
System Control Engineering	•				•	☑			
Automotive Management	☑		☑	☑	•	☑	•	☑	
Advanced Vehicle Control	☑		☑		•	☑	•		•
- Project vehicle control	☑	☑	•	☑	☑	☑	•		•
Advanced Powertrains	•		☑		•	☑	•		☑
Intelligent Vehicle Highways	☑		☑		•	☑	☑	•	☑
Major thesis project	☑	☑	☑	☑	☑	☑	☑	☑	☑

Table 1 Modules vs. final qualifications

Workload of the curriculum

The workload in terms of hours (contact, personal work and self-study) per module is given in table 2 (full-time programme) and tabel 3 (part-time programme).
The full-time programme takes 1.5 years, with a total load of 90 EC including 30 EC major master thesis. This means about 40 hours per week, based on 21 weeks per semester. With 14 weeks scheduled for contact hours, the contact hours vary between 20 and 26 per week, with the exception of period 2. The average amounts 21 contact hours a week. In period 2, a minor project is carried out requiring more personal hours, and the contact hours amount 32. The total workload (excluding the final thesis project) is about 2.8 times the number of contact

hours. In the weeks with contact hours, the ratio between contact and personal work (self-study, projects, assignments,…) is in average about 1 : 0.9.
The final thesis is scheduled to be carried out within half a year. There will be a significant pressure on the student by the master supervisor to finish within this time, according to commitment to the hosting company. If, however and in spite of this strong guidance, the result is not acceptable, this period will be extended.
Experience shows that this workload is feasible if the student is prepared to put sufficient energy in the course including self-study, and attends the lectures and practices. The regular verifications (examinations every period, exercises, assignments and so on) will give the student an effective feed-back on his/her progress.

	Feb-Apr			Apr-Jun			Sep-Oct			Nov-Jan							
FULL-TIME																	
Modules	Contact hours	Personal work	Total period 1	Contact hours	Personal work	Total period 2	Contact hours	Personal work	Total period 3	Contact hours	Personal work	Total period 4	Contact hours	Personal work	Total semester 3	Total module	Total EC
IAS	28	42	70			0			0			0			0	70	2.5
MM	28	42	70			0			0			0			0	70	2.5
CBT	32	40	72	16	24	40			0			0			0	112	4
VDV	32	40	72	16	24	40			0			0			0	112	4
DT	32	40	72	16	24	40			0			0			0	112	4
PMS	32	32	64	24	24	48			0			0			0	112	4
MINOR			0	32	220	252			0			0			0	252	9
AVD			0			0	28	28	56	28	28	56			0	112	4
- mod/sim.			0			0	12	16	28			0			0	28	1
- project			0			0			0	16	40	56			0	56	2
AVC			0			0			0	28	56	84			0	84	3
- project			0			0			0	4	24	28			0	28	1
VE			0			0	46	66	112			0			0	112	4
- lab. Aut.			0			0	12	16	28			0			0	28	1
SCE			0			0	32	52	84	16	12	28			0	112	4
AM			0			0	32	80	112			0			0	112	4
APT			0			0			0	40	44	84			0	84	3
IVHS			0			0			0	20	64	84			0	84	3
THESIS			0			0			0			0		840	840	840	30
Total (hrs)	184	236	420	104	316	420	166	254	420	140	280	420	0	840	840	2520	90
Total(EC)			15			15			15			15			30	90	

Table 2 Workload, full-time programme

The duration of the part-time programme is 2 years excluding the final thesis. The thesis is expected to be carried out in-company, employing the student. In general, it is envisaged (and stimulated) that the final thesis is carried out within one year. It may be well possible that the company allows the student to work on a suitable project full-time. In that case, the duration of the final thesis project can be less than 1 year. This is to be discussed with the hosting company. In any case, duration for the final thesis project exceeding one year will be discouraged.

The workload for part-time students will be about 20 hours per week. Contact hours amount an average of 12 hours per week, and the total workload (excluding the final thesis) is about 2.9 times the number of contact hours. In the weeks of contact, the ratio between contact and personal hours (self-study) is 1 : 0.7.

	Feb-Apr			Apr-Jun			Sep-Okt			Nov-Jan			Feb-Apr			Apr-Jun			Sep-Okt			Nov-Jan					
PART-TIME																											
Modul.	Contact hours	Personal work	Total per. 1	Contact hours	Personal work	Total period 2	Contact hours	Personal work	Total period 3	Contact hours	Personal work	Total period 4	Contact hours	Personal work	Total period 5	Contact hours	Personal work	Total period 6	Contact hours	Personal work	Total period 7	Contact hours	Personal work	Total period 8	Total thesis	Total module	Total EC
IAS	24	46	70			0			0			0			0			0			0			0	0	70	2.5
MM	24	46	70			0			0			0			0			0			0			0	0	70	2.5
CBT	24	30	54	24	34	58			0			0			0			0			0			0	0	112	4
VDV			0	24	34	58	22	32	54			0			0			0			0			0	0	112	4
DT			0	24	34	58	22	32	54			0			0			0			0			0	0	112	4
PMS			0	12	24	36	28	32	60			0			0			0			0			0	0	112	4
MINOR			0			0	12	30	42	20	198	210			0			0			0			0	0	252	9
AVD			0			0			0			0	32	32	64	24	24	48			0			0	0	112	4
- mod/sim			0			0			0			0	12	16	28			0			0			0	0	28	1
- project			0			0			0			0	8	20	28	8	20	28			0			0	0	56	2
AVC			0			0			0			0			0			0			0	28	56	84	0	84	3
- project			0			0			0			0			0			0			0	4	24	28	0	28	1
VE			0			0			0			0			0	24	38	62	22	28	50			0	0	112	4
- lab aut.			0			0			0			0			0			0	12	16	28			0	0	28	1
SCE			0			0			0			0	32	52	84	16	12	28			0			0	0	112	4
AM			0			0			0			0			0			0	24	88	112			0	0	112	4
APT			0			0			0			0			0	22	28	50	18	16	34			0	0	84	3
IVHS			0			0			0			0			0			0			0	20	64	84	0	84	3
THESIS			0			0			0			0			0			0			0			0	840	840	30
Total (hrs)	84	126	210	84	126	210	84	126	210	20	190	210	84	120	204	94	122	216	76	148	224	52	14	196	840	2520	90
Total (EC)			7.5			7.5			7.5			7.5			7.3			7.7			8			7	30	90	

Table 3 Workload, part-time programme

Each Module is closed with one or two written examinations, plus assessment of additional results such as assignment report, project report, oral presentations, task accomplished or laboratory report.

Responsibility

The master programme is carried out under the supervision of HAN-Automotive Research being the combination of professorships ("lectoraten") Mobility Technology and Vehicle Mechatronics, and the Applied Research Laboratory Automotive (ARLA) of the HAN. HAN-Automotive is carrying out research projects for the automotive industry, and includes about 25 staff members in total (part-time and full-time).

Appendix Description of modules

This descripes all the modules, offered as part of MAS.

We note that all module results referring to communication (team process, oral presentation, reporting,…) will be separately and explicitly commented with respect to these communication skills (in addition to the content).

<table>
<tr><th>Module</th><th>IAS: Introduction Automotive Systems</th></tr>
<tr><td>Objectives</td><td>To make the student familiar with the area of automotive engineering
The student will understand both the value of the separate R&D fields as well as their interrelated consequences on safety, environment and fuel efficiency.
To have a common basis for the rest of the programme, and to remove possible existing deficiencies in knowledge as well as communication skills.
The student will have a first experience in practicing research and communication skills in the sense of analysing a problem area (multidisciplinary, not well described and implicitly defined), bringing it in a more general context (abstract level), proposing feasible solutions and defending these.</td></tr>
<tr><td>Credits</td><td>2.5</td></tr>
<tr><td>Teaching/Study methods</td><td>Interactive lecturing, guest lectures, team assignment, presentation, literature survey</td></tr>
<tr><td>Content</td><td>A general introduction to automotive systems is given including:
A general layout of the vehicle design, on both functional and technical level
The present challenges regarding safety, environment and fuel efficiency, the efficiency of our traffic system (congestion), including the contribution of the vehicle to this.
The global economic developments in a historical perspective, its consequences to the automotive industry, trends as cost-reduction and the shift of added value from OEM to supplier (and further down in the supply chain).
Technical developments up to now and expected developments (road-map) in the future.
Safety, driver support, sensing the vehicle environment, x-by-wire., speed and steering control, collision avoidance,…
Emissions and fuel economy, hybrids and diesels, fuel cells, flexible fuel systems,…
Transmission, AMT, wheel torque control and torque distribution, coordination of engine and transmission control, shift-by-wire and DCT,..
The smart car, an intelligent platform with an increasing number of processors requires new design approaches, vehicle architecture, vehicle and driver state estimation
This introduction will include a number of guest lectures by people from the professional field. In this module, the focus will always be on the integrated vehicle platform and its interfacing with the communication and physical infrastructure, other road users and the driver. In addition, one of the lectures will be devoted to communication skills (oral, reporting).

Each student will establish a persuasive argumentation (in writing) on a problem area, and defend it to a group of other students who play the role of a customer.
Examples of problem areas:
The use of biofuels
From 12 V to higher voltage batteries
Driver support, reducing or increasing traffic safety?
Customization: downsizing or SUV?</td></tr>
<tr><td>Assessment</td><td>Case studies: argumentation (validity, use of research skills, technical contents), defence and communication</td></tr>
</table>

Workload	70 working hours including 28 contact hours (full-time) or 24 contact hours (part-time)
Course material	Lecturing material and hand-outs, trend-reports (Power Point, Scholar)

Module	**MM: Mathematics and Mechanics**
Objectives	1. To have a common basis in mathematics and mechanics, and to remove possible existing deficiencies in knowledge 2. Students are able to apply mathematical and mechanical theories at a level as required for the master course (model formulation, analysis, synthesis).
Credits	2.5
Teaching/Study methods	Interactive lecturing, take home exercises
Content	The intake requirements should guarantee that students can identify the main issues and have a sufficient theoretical background to be able to understand and to solve elementary mathematical and mechanical problems. This module serves that the student has a working knowledge, meaning that he/she is able to apply the theories in (smaller) practical problems. This module covers the following areas in mathematics: ▪ Linear algebra and vector analysis in space ▪ Differential and integral calculus of single variables ▪ Differential calculus of multiple variables ▪ Analytical geometry in 2-D space (line, curves of 2nd order) ▪ Ordinary differential equations (initial and boundary conditions, numerical methods of integration) ▪ Complex numbers ▪ Laplace transformation ▪ Taylor expansion ▪ Linear differential equations of n-th order and sets of linear differential equations ▪ Elementary numerical methods (iteration, integration routines) The module covers the following areas in mechanics: ▪ Equilibrium conditions of planar and spatial system of forces, free body diagram ▪ Basic cases (beams) of stress – deformation, statically indefinite cases, limit states – modes of failure (tension and pressure, bending, torsion, combined cases, fatigue) ▪ Kinematics of planar (2-D) motion of a body (centre of instantaneous rotation, analysis of velocity and acceleration components,...) ▪ Vibrations with multiple DOF - free vibrations, excited vibrations ▪ Dynamics of 2-D general motion of a body (rotation of a rigid body, moment of inertia, calculation of dynamic forces for 2-D cases)
Assessment	Written examinations, take home exercises completed
Workload	70 working hours including 28 contact hours (full-time) or 24 contact hours (part-time)
Course material	[1]. E. Kreyszig.: Advanced Engineering Mathematics, John Wiley & Sons, ISBN 0-471-72897-7 [2]. Handout mechanics, based on the books by Meriam and Kraige (Engineering Mechanics) and Hibbeler (statics, dynamics, structural analysis)

Module	PMS: Practice modelling and simulation
Objectives	1. Students have a basis knowledge in Matlab-SIMULINK-SIMECHANICS 2. Students are able to translate a real-life problem to a model at an abstract level, and to interpret and communicate the results, using tools from the MATLAB-SIMULINK family. 3. Students are able to manage their learning process by critically (qualitatively) assessing their modelling results against real-life situation and problem formulation.
Credits	4
Teaching/Study methods	Lecturing, interactive simulation exercises, take home assignments, reporting, oral presentation
Content	This module has three levels of applications of Matlab-SIMULINK-SIMMECHANICS tools: 1. a general introduction with applications (exercises at the HAN, take home), based on the problem areas treated in module MM. This includes a number of mathematical exercises (linear algebra, differential equations and solution space, time- and frequency/Laplace domain, iteration as part of solving nonlinear differential equations). It also includes a number of mechanical problems (quarter and half-vehicle models, kinematics and dynamics of a 2D motion, pendulum, multi-bar system, McPherson and Wishbone suspension,). 2. analysis of existing larger automotive models (by each student separately) from the Matlab demo collection, or from the collection of models derived from real-life problems by the HAN-University (vehicle suspension, articulated vehicle, hybrid propulsion system,..). Each student will deal with one of such problems, related to the physical and automotive topics treated in module IAS. 3. modification of an existing model (trend analysis) and interpretation of results. Students will present their results briefly to their colleague students, with these results being criticised, discussed and assessed by the group, and then (including this feedback) reported individually.
Assessment	Feed-back on model achievements through group assessment. Report and presentation.
Workload	112 working hours including 56 contact hours (full-time) or 40 contact hours (part-time)
Course material	• W.D. Pietruszka.: Matlab und Simulink in der Ingenieurpraxis. Modellbildung, Berechnung und Simulation. Teubner (2005) • Matlab/SIMULINK software • Lecturing material and hand-outs (Power Point, Scholar)

Module	VDV: Vehicle Dynamics & Vibrations
Objectives	1. To understand lateral and longitudinal vehicle handling behaviour under normal (low-speed as well as high-speed) conditions. 2. Students are able to analyse road-holding and comfort problems for vehicles 3. Students are able to derive and apply abstract models 4. Students are able to understand and analyse a scientific paper on Vehicle Dynamics
Credits	4
Teaching/Study methods	Lecturing, guest lectures, literature survey, reporting
Content	The module 'Vehicle Dynamics and Vibrations' includes the general vehicle dynamics topics and tools. The following topics are treated: ▪ Basics of tyre technology ▪ Basics of linear lateral dynamics ▪ Basics of longitudinal dynamics, braking, driving, pitch ▪ Criteria of good handling performance ▪ Equations of motion and modelling of vehicle performance ▪ Judgement of comfort and road holding ▪ Kinematics of the suspension system ▪ Wheel- and axle kinematics, kinematics of the suspension system ▪ Comfort analysis and the impact of road disturbances to vehicle performance

	In addition to a written examination, in order to judge the student performance, a small assignment has to be carried out, being representative for the course material. This includes limited literature survey, and has to be delivered as a report.
Assessment	Written examinations (2), report (literature survey)
Workload	112 working hours including 48 contact hours (full-time) or 46 contact hours (part-time)
Course material	<u>Literature, prescribed to students:</u> [1]. Lecturing material and hand-outs (Power Point, Scholar) [2]. G. Genta.: *Motor Vehicle Dynamics*, World Scientific, ISBN nr. 9810229119

Module	**CBT: Combustion Engines and Thermodynamics**
Objectives	1. To understand the basics of combustion engines and the underlying thermodynamics background 2. Students are able to derive and apply abstract models 3. Students are able to understand and analyse a scientific paper on Combustion Engines
Credits	4
Teaching/Study methods	Lecturing, guest lectures, literature survey, reporting
Content	The module "Combustion Engines and Thermodynamics" covers the following topics: *Thermodynamics* ▪ conservation of mass and energy for fluids (mass conservation, 1st law of thermodynamics) ▪ Bernoulli equation for one dimensional flow ▪ basic reversible changes of perfect gas ▪ Irreversible changes and 2nd law of thermodynamics, entropy ▪ Basic cases of steady heat transport (conduction, heat transfer, radiation) *Combustion engines* ▪ Principles of Internal combustion engines (engine map, engine cycles, thermal efficiency, chemistry of combustion, SI, CI) ▪ Fuels, fuel injection, mixture formation ▪ Emissions ▪ Engine performance and maps ▪ Elementary engine modelling ▪ Engine management (concepts, air-fuel ratio and lean/rich operation, fuel injection) ▪ Engine control (Lambda) In addition to a written examination, in order to judge the student performance, a small assignment has to be carried out, being representative for the course material. This includes limited literature survey, and has to be delivered as a report.
Assessment	Written examinations (2), report (literature survey)
Workload	112 working hours including 48 contact hours (both full-time and part-time)
Course material	<u>Literature, prescribed to students:</u> [1]. Lecturing material and hand-outs (Power Point, Scholar) [2]. Engineering Fundamentals of the Internal Combustion Engine van Willard W.Pulkrabek ISBN 0-13-191855-9

Module	**DT: Driveline and Transmission**
Objectives	1. To understand the basics of driveline and transmission 2. Students are able to derive and apply abstract models 3. Students are able to understand and analyse a scientific paper on Drivelines and Transmissions
Credits	4
Teaching/Study	Lecturing, guest lectures, literature survey, reporting

methods	
Content	The module "Driveline and Transmission" covers the following topics: ▪ Longitudinal vehicle dynamics. Vehicle resistances, force equilibrium. Speed characteristics of vehicles. Optimal gear ratio definition. ▪ Driveline components (friction elements, clutch, transmission, shafts, differential, wheels) ▪ Elementary driveline equations ▪ Manually activated transmissions, mechanical transmission. Function, design and trends, determination of ratio, gear shift systems, calculation of geometry and stress of gears. ▪ Automatic transmission. Function, design and trends. Calculation of elementary gear sets: graphical method, ratio determination. Energetic study. Calculation of efficiency. ▪ Planetary trains. Calculation of nested planetary gear trains: graphical method, ratio determination. Energetic study. Calculation of efficiency. Conditions of assembly of planetary gear sets ▪ CVT ▪ Hydraulic transmissions ▪ 4-wheel drives ▪ Drive shaft and joints. In addition to a written examination, in order to judge the student performance, a small assignment has to be carried out, being representative for the course material. This includes limited literature survey, and has to be delivered as a report.
Assessment	Written examinations (2), report (literature survey)
Workload	112 working hours including 48 contact hours (full-time) or 46 contact hours (part-time)
Course material	Literature, prescribed to students: [1]. Lecturing material and hand-outs (Power Point, Scholar) [2]. G. Lechner, H. Naunheimer.: *Automotive transmissions*. Springer

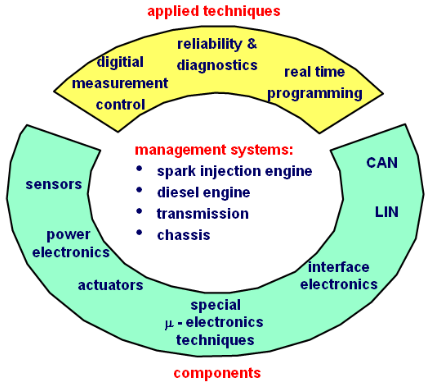
Module	**AVD: Advanced Vehicle Dynamics including modelling/simulation practice and project**
Objectives	1. To understand vehicle (passenger car, articulated vehicle, motorcycle) handling behaviour under normal and extreme conditions, also accounting for the vehicle-driver interface. 2. Students are able to derive and apply abstract models 3. Students are able to apply this knowledge for real-life problems, including modelling and testing
Credits	7 (including 1 ECTS for modelling practices, and 2 ECTS for the project)
Teaching/Study methods	Lectures, guest lectures, team assignment (incl. experimental research), interactive simulation practices, literature survey, oral presentation, reporting
Content	This module covers the following specialized topics: ▪ Accident analysis (reconstruction of accidents, impulsive model plus more advanced approach accounting for crash performance) ▪ Vehicle performance (handling, stability) taking full account of the nonlinear tyre behaviour (limit behaviour). Nonlinear equations of motion, with emphasis on (graphical) methodologies like phase plane analysis and (local/global) non-linear stability theory. ▪ Transient and dynamic tyre behaviour, with distinction between relaxation effects (first order dynamics) and high-frequency rim-dynamics being important for the design of active control systems. ▪ Dynamics of articulated vehicles such as car-caravan and commercial vehicle combinations, including a discussion of truck tyres, vehicle behaviour and stability properties in relationship to their design properties. This includes low speed and high speed straight line performance, low speed and high speed turning, vehicle-infrastructure interaction and tilting risk.

	▪ How to model the human controller. Driver closed loop performance is discussed at various levels of complexity and with emphasis to the human controller adaptive nature. Subjective assessment of vehicle performance, and mental/visual workload measures ▪ Motorcycle behaviour covering kinematics of the motorcycle, motorcycle tyres, steady state cornering, and the motorcycle modes of stability (capsize, weave, wobble). Closed loop rider control. Two practices will be devoted to the derivation, application and interpretation of models (1) articulated vehicles and (2) closed loop vehicle-driver steering performance Students have to carry out an assignment including a literature survey, of which model development and analysis as well as (vehicle instrumentation and) experimental validation and parameter identification are essential parts. Examples are: - to improve a chassis design through damper adjustment - to derive and validate an experimental way to identify and analyse driver control parameters (gains, lead- and lag times, delay time,..)
Assessment	Written examination (2), task accomplished (simulation practices), report and presentation (project)
Workload	196 working hours including 84 contact hours (both full-time and part-time)
Course material	<u>Literature, prescribed to students:</u> [1]. Lecturing material and hand-outs (Power Point, Scholar) [2]. G. Genta.: *Motor Vehicle Dynamics*, World Scientific, ISBN nr. 9810229119 <u>Other major sources, used in the preparation of the lectures and adviced to students:</u> [1]. R.J. Jagacinski, J.M. Flach.: *Control Theory for Humans*, ISBN nr. 0805822925 [2]. H.B. Pacejka.: *Tyre and Vehicle Dynamics*, Butterworth Heinemann, Oxford (2005) ISBN nr. 0750651415 [3]. V. Cossalter.: *Motorcycle Dynamics* (2006), ISBN nr. 978 – 1 – 4303 – 0861 – 4 [4]. J.P. Pauwelussen.: *Graphical Means to Analyze and Visualize Vehicle Handling Behaviour*, ECCOMAS Thematic Conference in Multibody Dynamics 2005, Madrid [5]. J.P. Pauwelussen, W. Dalhuijsen.: *Tyre as a Vehicle Component*, 4 ECTS module of VERT: Virtual Education in Rubber Technology. EU Leonardo project FI-04-B-F-PP-160531 (2007) [6]. P.Sweatman (ed.).: *PBS Explained, Performance Based Standards for Road Transport Vehicles*, report Australian Road Transport Suppliers Association (2003)

Module	**AVC: Advanced Vehicle Control including project Vehicle Control**
Objectives	1. To provide students with a good understanding of the control of vehicle performance, based on approximation and identification of vehicle parameters and estimation of vehicle states, and in relationship with its environment (traffic conditions, road- and weather conditions, the driver as the prime observer and controller). 2. Students are able to understand, interpret and apply system based vehicle control literature.
Credits	4 including 1 ECTS for the project Vehicle Control
Teaching/Study methods	Lectures, assignment (model approach), literature survey, reporting
Content	The core area here encompasses dynamic system behaviour and control technology, with a prominent role for discoveries in the field of mechatronics (modern vehicle control) and the driver-vehicle interface, with the fundamental vehicle dynamics aspects as a firm basis. Vehicle control can be approached in physical design terms and from a functional system point of view. After an extensive introduction on the design characteristics, this module is largely focused on the last approach, with emphasis on vehicle state estimation and vehicle parameter identification and approximation. We follow the book of Kiencke and Nielsen. This results in the following module topics: • Introduction to vehicle dynamics control, the driver transport mission, integrated

	control. • Driver modelling, the ‘driver in the loop’, ADA: Advanced Driver Assistance • Workload and workload measures • Brake and drive control • Refined vehicle modelling, wheel model, vehicle model, model validation • Vehicle states estimation (velocity, yaw rate) using Kalman filtering, fuzzy control • Parameter identification (friction, inertia, shock absorber characteristics) using recursive least squares • Approximation of vehicle parameters (contact forces, tyre side slip, pitch and roll, vehicle mass) • Observation (pseudo sensor) of vehicle body side slip and road gradient • Application to ABS and yaw dynamics control. In order to bridge the gap between theory and practical use of this theory, the students have to carry out an assignment and present the results, in addition to a written examination. All material (small report, simulation results and model files) is part of the assessment. This assignment will be changed every year. Examples of such assignments are: - to analyse an existing paper (Abe et. al) on integrated control using optimal control methods and sliding mode techniques with the following subtasks: 1. to reproduce the simulation results for the controlled vehicle performance 2. to suggest ways to apply the theory in a practical way 3. to explain optimal control methods and sliding mode techniques in more detail - to derive the body slip observer according to Kiencke and Nielsen [2] within a Matlab-Simulink environment. To demonstrate its validity based on experimental vehicle data within a full range of linear (low lateral acceleration) to nonlinear (large acceleration) vehicle behaviour.
Assessment	Written examination, assignment report.
Workload	112 working hours including 32 contact hours (both full-time and part-time)
Course material	Literature, prescribed to students: [1]. Lecturing material and hand-outs (Power Point, Scholar) [2]. U. Kiencke, L. Nielsen.: *Automotive Control Systems*, chapters 8, 9 and 10. Springer-Verlag (2005), ISBN nr.: 3 – 540 – 32139 – 0 Other major sources, used in the preparation of the lectures and adviced to students: [1]. R.J. Jagacinski, J.M. Flach.: *Control Theory for Humans*, ISBN nr. 0805822925 [2]. H. Wallentowitz, K. Reif.: *Handbuch Kraftfahrzeugelektronik, Grundlagen, Konponenten, Systeme, Anwendungen*, ATZ/MTZ Fachbuch (2006), ISBN nr. 3 – 528 – 03971 – X [3]. Conference proceedings such as AVEC (Advanced Vehicle Control), IFAC (Symposia on Automotive Control)

Module	**VE: Vehicle Electronics including lab autotronics**
Objectives	1. to provide students with a good understanding of the operation of intelligent systems, management systems and processes together with detailed knowledge of the applied components such as sensors and actuators 2. students are able to select or specify components for management systems, 3. students are able to perform complex diagnostics and fault finding on management systems
Credits	5 (including 1 ECTS for Lab Autotronics)
Teaching/Study methods	Lectures, experimental research and lab exercises, (interactive) case studies and oral presentation
Content	The module handles 3 levels, (1) system level, (2) component level and (3) applied techniques, as schematically shown in figure A.1 At system level, distinction is made between spark injection engine management systems, diesel management systems, transmission management systems and chassis management systems. At component level, the module discusses sensors, actuators, interface electronics, power

	electronics, microcontroller techniques with special emphasis on I/O such as ADC and timers, and communication protocols according to CAN and LIN conventions. At the applied techniques level, the module treats real time programming, digital measurement and control techniques, and reliability and diagnostics.  **Figure A.1: Module Vehicle Electronics** The module on Vehicle Electronics covers the following elements, to be assessed through written examination, laboratory reports, case study and case presentation: • The use of simulating techniques of electronic circuits • The use of electronic measurement equipment, such as multimeter and oscilloscope • Computing of electrical behaviour of sensors and actuators and creating mathematical models for this behaviour • Specification and design of interface circuits for sensors and actuators • All electrical interference problems and solutions, specially for in car applications • Architecture, protocols and information base of CAN and LIN networks • Causes of failures of electric components in car applications • Methods of improving safety, reliability, diagnostics of management systems and components In addition to theory lessons, the students will carry out 3 x 4 hours laboratory exercises, as well as a case study (including presentation).
Assessment	Written examination (1), laboratory report, oral presentation (case study)
Workload	140 working hours including 58 contact hours (both full-time and part-time). Contact hours include 12 hours laboratory exercises (Lab Autotronics)
Course material	Literature, prescribed to students: [1]. Lecturing material and hand-outs (Power Point, Scholar) [2]. A. Visser.: *Reader Vehicle Electronics, nr. 5417* Literature, advised to students: [1]. R.K. Jurgens.: *Automotive Electronics Handbook*, McGraw-Hill, ISBN nr. 07 – 034453 – 1

Module	**SCE: System Control Engineering**
Objectives	1. to introduce students in control systems, in the basic features and configurations of control systems, and in analysis and design process and objectives. 2. To contribute to the student knowledge and skills in applying system control engineering tools
Credits	4
Teaching/Study methods	Lectures, laboratory exercises using Matlab and Simulink
Content	The module covers the following topics. Poles, zeros and system time response. First and second order systems. System response with additional poles. System response with zeros. Effects of non-linearities upon time response. Reduction of multiple systems block diagrams. Analysis and design of feedback systems. Signal-flow graphs, Manson's rule. Stability, Routh-Hurwitz criterion and special cases. Steady state errors for unity feedback systems, static error constants and system type, specification. Steady-state error for disturbances and nonunity feedback systems. Frequency response techniques, Bode plots, Nyquist criterion, stability via the Nyquist diagram, gain margin and phase margin. Relation between closed-

	loop transient and closed loop frequency responses, relation between closed- and open-loop frequency responses, relations between closed-loop transient and open-loop frequency responses. Steady state error characteristics from frequency response. Systems with time delay. Obtaining transfer functions experimentally. Design via frequency response. Transient response via gain adjustment, lag compensation, lead compensation, lag-lead compensation. Measurement/evaluation of step response of physical system modelling of system, measurement of frequency-response (transfer-function) of system refining model, design of cascade controller via frequency-response and root-locus techniques, actual implementation and evaluation of a controller.
Assessment	Written examination (2) and laboratory exercise results (accomplished, reported)
Workload	112 working hours including 48 contact hours (both full-time and part-time).
Course material	Literature, prescribed to students: [1]. Lecturing material and hand-outs (Power Point, Scholar) [2]. N.S. Nise.: *Control Systems Engineering*, 3rd edition, John Wiley & Sons (2000), ISBN nr.: 0 – 471 – 36601 – 3

Module	**AM: Automotive Management**
Objectives	1. The student has a broad and systematic insight into the dynamic world of automotive companies, their driving forces and policies, concepts, working processes as well as their business and technical solutions to survive in a competitive environment. The complete landscape and value chain of the automotive sector will be discussed against the latest state. 2. The student understands the multi-disciplinary and macro-economical context in which vehicles are designed 3. The student understands automotive company processes, with focus on deriving a competitive automotive end-product, and he/she is able to address existing problems to those processes and define improvements and solutions to them. 4. The student is knowledgeable about the major automotive developments and their impact on the international business, of quality systems and he/she is able to develop competencies to improve quality in different working processes. 5. The student is able to translate technological innovations into business cases on the strategic level of automotive companies, to develop strategic and management competencies to support the definition of strategic business problems and marketing opportunities, and to make management recommendations regarding implementation of business improvements, new products or processes. 6. The student is able to give direction to a process of ever increasing pressure on cost-levels and time-to-market within the borders in which research and development processes are shaped, and he/she is able to translate international environmental and social economic developments into new targets for process research and development
Credits	4
Teaching/Study methods	Lectures and guest lectures, with additional practical hours scheduled for self-study, assignments (individual case studies, group assignment/ management game).
Content	Within the module on Automotive Management, four different submodules are distinguished: *I Automotive landscape* This deals largely with strategic issue's, business trends, product trends and market trends *II Automotive value chain* From sketch till scrap; the total value chain. Product lifecycle management. The production chain and logistics principles. *III Automotive working processes* Organisation models. Simultaneous engineering. Lean production. Factory control, management theories. *IV Quality models* General Quality models as EFQM,ISO,TS. Quality in the design process, and in the production process. The Toyota model (culture)

Assessment	The required skills and knowledge are assessed through a written examination, group cases (management games) and individual cases
Workload	112 working hours including 32 contact hours (full-time) and 24 hours (part-time).
Course material	<u>Literature, prescribed to students:</u> [1]. Lecturing material and hand-outs (Power Point, Scholar) <u>Other major sources, used in the preparation of the lectures and advised to students:</u> [1]. Journals like: Automotive Engineering and AutoTechnology. [2]. Automotive management "*Strategie und Marketing in der Automobilwirtschaft*". Springer Verlag, ISBN nr. 354000226X [3]. P. and N. Atwood.: *Logistics of a distribution system*. Gower Publishing Company (1992), ISBN nr. 566090988 [4]. S. Newburry.: *The car design yearbook*, Merrell Publishers Limited, London (2002) [5]. O. van Fersen.: *Ein Jahrhunderd Automobiltechnik*, VDI Verlag, Düsseldorf (1986), ISBN nr. 3-18-400620-4.

Module	**APT: Alternative Powertrains**
Objectives	1. The student has a working knowledge on the development of cleaner vehicles, with focus on clean fuels and new powertrain and driveline concepts, e.g. synthetic fuels, bio fuels (ethanol, DME,…), natural gas, hybrid vehicles, hydrogen. 2. The student understands these developments from an in-depth technological as well as a socio-economic point of view.
Credits	3
Teaching/Study methods	Lectures, plus a small thesis on a selection of the topics. The thesis (based on experiments) will be linked with one of the various demonstrators at the HAN in the field of (hydrogen based) hybrid propulsion, the HAN Hydrogen Laboratory and/or one of the engine test beds. All of these items has been established or is used as part of research projects at the HAN.
Content	 **Figure A.2.: HAN testvehicle, adjusted for hydrogen-natural gas blends** The outline of the module is described as follows: • Relationship between emissions and global warming as well as health issues. Why are emissions like NO_x, CO_2, particles, etc. so critical with respect to global warming and climate change, and what is the impact on health? • What is the status with respect to emissions, and what are the international ambitions in terms of agreements (Kyoto, EU-policies) and regulations (ECE, EURO 4, EURO 5,..). • "Well to tank"- analysis and "well to wheel"- analysis. Consideration of the full energy transfer and conversion chain, with all the intermediate consequences in terms of energy efficiency and environmental impact.

	• Technological vehicle-innovation with a distinction between:
	    o fuels (CNG, conventional fuels, bio fuels, electric energy,…)
	    o energy storage, conversion (fuel cells),..
	    o power source and its control, ICE, electromotor, motor management
	    o after treatment
	In-depth treatment of the various technical concepts.
	• What has been achieved so far, clean vehicles that have been introduced to certain markets
	• Developments at the middle and long term (bio fuels, hydrogen)
	• Developments at the short term (hybrid, natural gas, electric, improved diesels,..)
	• Examples of clean vehicles

Assessment	Written examination, plus thesis assessment.
Workload	84 working hours including 40 contact hours (both full-time and part-time).
Course material	<u>Literature, prescribed to students:</u> [1]. Lecturing material and hand-outs (Power-Point, Scholar) <u>Other major sources, used in the preparation of the lectures and advised to students:</u> [1]. L. Guzella.: Vehicle Propulsion Systems, Springer Verlag, ISBN nr. 13978 – 3 – 540 – 25195 – 8

Module	**IVHS: Intelligent Vehicle Highway Systems**
Objectives	1. The student is able to judge vehicle design within the framework of an intelligent traffic system. The focus is still on the vehicle. The surrounding traffic partners, the infrastructure, the driver (as controller, but also as a navigator) will be addressed in this module. 2. The student is able to formulate and assess the impact of an advanced traffic environment (e.g. intelligent traffic guidance) on safety, environment and traffic efficiency
Credits	3
Teaching/Study methods	Lectures, guest lectures, assignments based on the lectures.
Content	The module focuses on the following topics: • Tracking control, with the vehicle-driver system finding its way (semi-) automatically, with or without support of the driver along a certain path. Both path-following and optimal path design (for example in case of overtaking or merging in an automated platoon) • Automated vehicle guidance, with a discussion of recent developments, including topics like intelligent merging, ACC/stop and go, with chain stability taken into account • ADA systems, especially focussing on the increasing amount of support systems inside the cabin, and its impact in driver attention, safety, etc. • Local area and global area mobile communication • Lane departure warning systems • Intelligent logistics and chain management • Special examples of Automated Guided Vehicles, cyber cars and people movers. • Object recognition (traffic signs, passing pedestrians,..) and classification • Collision warning and avoidance
Assessment	Written examination, assignments being carried out (reports)
Workload	84 working hours including 20 contact hours (full-time and part-time).
Course material	<u>Literature, prescribed to students:</u> [1]. Lecturing material and hand-outs (Power-Point, Scholar) [2]. R. Bishop.: Intelligent Vehicle Technology and Trends, Artech House, ISBN nr. 1 – 58053 – 911 – 4