MECHANICAL ENGINEERING

DEPARTMENT OF MECHANICAL ENGINEERING

EINDHOVEN UNIVERSTIY OF TECHNOLOGY

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REPORT ON THE BACHELOR'S PROGRAMME MECHANICAL ENGINEERING AND THE MASTER'S PROGRAMME MECHANICAL ENGINEERING OF EINDHOVEN UNIVERSITY OF TECHNOLOGY

This report takes the NVAO's Assessment Framework for Limited Programme Assessments as a starting point (September 2016).

ADMINISTRATIVE DATA REGARDING THE PROGRAMMES

Bachelor's programme Mechanical Engineering

Name of the programme:	Mechanical Engineering (Werktuigbouwkunde)
CROHO number:	56966
Level of the programme:	bachelor's
Orientation of the programme:	academic
Number of credits:	180 EC
Specializations or tracks:	Mechanical Engineering
Location(s):	Eindhoven
Mode(s) of study:	full time
Language of instruction:	Dutch
Expiration of accreditation:	31/12/2019

Master's programme Mechanical Engineering

Name of the programme:	Mechanical Engineering
CROHO number:	60439
Level of the programme:	master's
Orientation of the programme:	academic
Number of credits:	120 EC
Specializations or tracks:	Polymer Technology Mechanics of Materials Micro Systems Multiphase and Reactive Flows Energy Technology & Fluid Dynamics Dynamics & Control Control Systems Technology
Location(s):	Eindhoven
Mode(s) of study:	full time
Language of instruction:	English
Expiration of accreditation:	31/12/2019

The visit of the assessment panel Mechanical Engineering to the Department of Mechanical Engineering of Eindhoven University of Technology took place on 11 and 12 December 2018.

ADMINISTRATIVE DATA REGARDING THE INSTITUTION

Name of the institution:	Eindhoven University of Technology
Status of the institution:	publicly funded institution
Result institutional quality assurance assessment:	positive

COMPOSITION OF THE ASSESSMENT PANEL

The NVAO has approved the composition of the panel on 20 August 2018. The panel that assessed the bachelor's and master's programme Mechanical Engineering consisted of:

- Prof. K.G.S. (Sören) Östlund, professor of Packaging Technology at the Department of Solid Mechanics of the KTH Royal Institute of Technology (Sweden) [chair];
- Prof. H.J. (Henry) Rice, professor in Mechanical Engineering and head of the School of Engineering, Trinity College, Dublin (Ireland);
- Dr. M. (Maddalena) Velonà, coordinator of studies at the Department of Mechanical and Process Engineering (D-MAVT) at Eidgenössische Technische Hochschule (ETH) Zürich (Switzerland);
- Drs. J.J. (Jan) Steen, consultant Quality of Education at Wageningen University & Research;
- Ir. L. (Leo) Kusters, managing director of AutomotiveNL, the cluster organization for the Dutch automotive industry, mobility sector and automotive education sector;
- Ir. M.J.E.H. (Marcel) Muitjens, senior director Environmental Control & Infrastructure at ASML Netherlands, a company that specialises in the development of hardware, software and services for (computer)chip manufacturers;
- C. (Coen) Bakker, BSc, master's student Mechanical Engineering, track High Tech Engineering, at Delft University of Technology [student member].

The panel was supported by dr. B.M. (Barbara) van Balen, who acted as secretary.

WORKING METHOD OF THE ASSESSMENT PANEL

The site visit to the bachelor and master programmes Mechanical Engineering and the master programme Automotive Technology at the Department of Mechanical Engineering of Eindhoven University of Technology was part of the cluster assessment Mechanical Engineering. In December 2018 the panel assessed eleven programmes at three universities. The following universities participated in this cluster assessment: Delft University of Technology, Eindhoven University of Technology and the University of Twente.

On behalf of the participating universities, quality assurance agency QANU was responsible for logistical support, panel guidance and the production of the reports. Dr. Alexandra Paffen was project coordinator for QANU. Dr. Barbara van Balen acted as secretary in the cluster assessment. She is a certified NVAO secretary.

Panel members
The members of the assessment panel were selected based on their expertise, availability and independence.

Preparation
On 9 December 2018, the panel chair was briefed by QANU on his role, the assessment framework, the working method, and the planning of site visits and reports. A preparatory panel meeting was organised on 9 December 2018. During this meeting, the panel members received instruction on the use of the assessment frameworks. The panel also discussed their working method and the planning of the site visits and reports.

The project coordinator composed a schedule for the site visit in consultation with the Department. Prior to the site visit, the Department selected representative partners for the various interviews. See Appendix 4 for the final schedule.

Before the site visit to Eindhoven University of Technology, QANU received the self-evaluation reports of the programmes and sent these to the panel. A thesis selection was made by the panel's chair and the project coordinator. The selection existed of fifteen theses and their assessment forms per

degree programme, based on a provided list of graduates between 2016-2017. A variety of topics and tracks and a diversity of examiners were included in the selection. The project coordinator and panel chair assured that the distribution of grades in the selection matched the distribution of grades of all available theses.

After studying the self-evaluation report, theses and assessment forms, the panel members formulated their preliminary findings. The secretary collected all initial questions and remarks and distributed these amongst the panel members.

At the start of the site visit, the panel discussed its initial findings on the self-evaluation reports and the theses, as well as the division of tasks during the site visit.

Site visit
The site visit to Eindhoven University of Technology took place on 11 and 12 December 2018. During the site visit, the panel studied the additional documents provided by the programmes. An overview of these materials can be found in Appendix 5. The panel conducted interviews with representatives of the programmes: students and staff members, the programme's management, alumni and representatives of the Examination Committee.

The panel used the final part of the site visit to discuss its findings in an internal meeting. Afterwards, the panel chair publicly presented the panel's preliminary findings and general observations.

Consistency and calibration
In order to assure the consistency of assessment within the cluster, the following measures were taken:
1. The panel composition ensured regular attendance of (key) panel members, including the chair;
2. The secretary was present at the start of all site visits as well as the panel discussion leading to the preliminary findings at all site visits of Delft University of Technology, Eindhoven University of Technology and the University of Twente.

Report
After the site visit, the secretary wrote a draft report based on the panel's findings and submitted it to the project coordinator for peer assessment. Subsequently, the secretary sent the report to the panel. After processing the panel members' feedback, the project coordinator sent the draft reports to the Department in order to have these checked for factual irregularities. The project coordinator discussed the ensuing comments with the panel's chair and changes were implemented accordingly. The report was then finalised and sent to the Department and University Board.

Definition of judgements standards
In accordance with the NVAO's Assessment framework for limited programme assessments, the panel used the following definitions for the assessment of both the standards and the programme as a whole.

Generic quality
The quality that, in an international perspective, may reasonably be expected from a higher education Associate Degree, Bachelor's or Master's programme.

Unsatisfactory
The programme does not meet the generic quality standard and shows shortcomings with respect to multiple aspects of the standard.

Satisfactory
The programme meets the generic quality standard across its entire spectrum.

Good
The programme systematically surpasses the generic quality standard.

Excellent
The programme systematically well surpasses the generic quality standard and is regarded as an international example.

SUMMARY JUDGEMENT

Bachelor's programme Mechanical Engineering

Standard 1
The bachelor's programme Mechanical Engineering is offered by the Department of Engineering of Eindhoven University of Technology (TU/e). Mechanical Engineering studies the analysis and synthesis of structures, machines, devices, systems, and processes that accomplish a desired objective in a safe, ethical, and sustainable fashion. According to the TU/e, the objective of the bachelor's programme is to serve as a solid basis in specific engineering domains, enabling further education at the master's level.

The bachelor's curriculum is made up of three key components: basic science (mathematics, physics, and thermodynamics), engineering courses (solid and fluid mechanics, dynamics, control) and integrating design projects. The objective is translated into ten intended learning outcomes (ILOs). The panel established that the ILOs are formulated in line with the mission and that they sufficiently indicate what could be expected from programmes at a bachelor's level. It also ascertained that the ILOs meet the internationally accepted description for academic bachelor's programmes, the Dublin descriptors. In its opinion, the ILOs are formulated on a general level, partly due to the structure of the TU/e bachelor college format with general skills and electives. It thinks that the ILOs could be more specific and tailored to the programme. They are specific enough, however, to fulfil the requirements for standard 1.

Standard 2
The bachelor's programme (180 EC) is structured according to the TU/e bachelor college format and contains 30 EC of basic courses, 90 EC of major courses, including the Bachelor Final Project (BFP), and an elective space (60 EC), including 45 EC of electives and a USE (User, Society, Enterprise) trajectory of 15 EC. The basic and major courses are mandatory.

The teaching method in most courses is a combination of plenary frontal lectures and guided self-study or instruction. The bachelor curriculum contains six Design-Based Learning projects, connected to the major courses. Design-Based Learning (DBL) is a problem-based, learning-inspired method in which students work on a problem in groups of six to ten. They apply previously acquired or new theoretical information and skills to find a solution to the problem or question presented.

The panel finds the alignment between the ILOs and the curriculum to be very good. It is very positive about the DBL projects and the learning lines that structure the curriculum. The whole bachelor's programme has a clear structure with well-developed learning lines and a close connection to research. The panel also appreciates the attention paid to the development of User, Society and Engineering competences in the USE line. Students receive a solid basis of scientific knowledge, combined with the development of soft skills and group work, and have enough possibilities to choose electives and build their own profile. The quality and quantity of the teaching staff are good.

Standard 3
The Department of Mechanical Engineering developed its own assessment policy, based on the TU/e framework. This policy applies to all of the Department's programmes and describes the instruments, procedures, and criteria for examinations, group work and individual projects. The panel established that the Examination Committee is adequately performing its legal duties and responsibilities. The programme has an adequate quality assurance system. There are procedures in place to assure the validity and reliability of the tests. The panel also ascertained that the examiners use adequate and transparent assessment forms.

Standard 4
The bachelor's programme prepares the students for continuing their studies in a master's programme. The panel studied a selection of 15 bachelor final projects to assess whether the

graduates had achieved the ILOs and concluded that they did achieve the level that can be expected of them. It found the bachelor final projects to be of a high level overall. The BFP reports showed that the bachelor students are qualified in the domain of engineering science and technology and are able to conduct research and design under supervision. They demonstrated a scientific approach to problems and ideas, based on current knowledge.

The panel assesses the standards from the *Assessment framework for limited programme assessments* in the following way:

Standard 1: Intended learning outcomes	satisfactory
Standard 2: Teaching-learning environment	good
Standard 3: Assessment	satisfactory
Standard 4: Achieved learning outcomes	good
General conclusion	good

Master's programme Mechanical Engineering

Standard 1
The master's programme Mechanical Engineering is offered by the Department of Engineering of Eindhoven University of Technology. The objective of the programme is to deliver mechanical engineers who are also science-oriented designers and design-oriented researchers. This objective is translated into ten intended learning outcomes. The panel appreciates that the programme is based on a clear mission and vision. The intended learning outcomes meet the Dutch qualifications framework. They sufficiently indicate the academic master's level and tie in with the international perspective of the requirements set by the professional field and the discipline.

Standard 2
The programme comprises core courses (20 EC), specialisation courses (20 EC), professional skills courses (5 EC), individual space (15 EC), an internship (15 EC), and a graduation project (45 EC). The students can choose out of eight specialisations in consultation with a coach. The internship provides experience in a real-life working environment. Most master students go abroad for their internship to another university, a research institute or a company. For their graduation thesis, students choose a topic related to the research in the departments.

The structure of the curriculum of the master's programme is comparable to that of other engineering master's programmes. The sound, thorough curriculum enables the students to achieve the intended learning outcomes. The panel appreciates the close connection to the research groups, which enables the students to achieve a high level in research. It endorses the plan to improve the study yields. The quantity and the quality of the teaching staff are good.

Standard 3
The Department of Mechanical Engineering developed its own assessment policy, based on the TU/e framework. This policy applies to all programmes and describes the instruments, procedures, and criteria for examinations, group work and individual projects. The panel established that the Examination Committee is adequately performing its legal duties and responsibilities. The programme has an adequate quality assurance system. There are procedures in place to assure the validity and reliability of the tests. The panel also established that the examiners use adequate and transparent assessment forms.

Standard 4
The panel studied a selection of 15 master theses to assess whether the graduates had achieved the intended learning outcomes and concluded that they did achieve the level that can be expected of

them. It found the theses to be of a high level overall and considers it very positive that the thesis topics are tied to industry. The assessment of the theses demonstrated a careful check of the outcomes; it showed that the graduates are able to conduct research and design independently, have a scientific approach to complex problems and ideas, and have the ability to seek new potential applications. They have a good basis for a start in the job market, for a PhD programme or in industry.

The panel assesses the standards from the *Assessment framework for limited programme assessments* in the following way:

Standard 1: Intended learning outcomes	satisfactory
Standard 2: Teaching-learning environment	good
Standard 3: Assessment	satisfactory
Standard 4: Achieved learning outcomes	good
General conclusion	good

The chair, professor Sören Östlund, and the secretary, dr. Barbara van Balen, of the panel hereby declare that all panel members have studied this report and that they agree with the judgements laid down in it. They confirm that the assessment has been conducted in accordance with the demands relating to independence.

Date: 26 March 2019

DESCRIPTION OF THE STANDARDS FROM THE ASSESSMENT FRAMEWORK FOR LIMITED PROGRAMME ASSESSMENTS

Governance structure of the Faculty
The bachelor's and the master's degree programmes Mechanical Engineering and the master programme Automotive Technology are offered by the Department of Mechanical Engineering of Eindhoven University of Technology (TU/e). The TU/e is a research-driven, design-oriented university of technology within the domain of Engineering Science & Technology. TU/e educates engineers who possess a solid scientific basis, in-depth knowledge and the necessary skills to be successful in a variety of societal sectors and functions. All bachelor's degree programmes of the TU/e are embedded in the Bachelor College, and all master's degree programmes are embedded in the Graduate School. This report contains the assessment of the bachelor's and master's degree programmes Mechanical Engineering. A separate report is dedicated to the assessment of the master programme Automotive Technology.

Standard 1: Intended learning outcomes
The intended learning outcomes tie in with the level and orientation of the programme; they are geared to the expectations of the professional field, the discipline, and international requirements.

Findings
The mission of the Department of Mechanical Engineering is to provide society with mechanical engineers equipped for and capable of working in industry, in society and with the science of tomorrow and the more distant future. The department strives to deliver a wide variety of engineers who can match the future demands of society. This means that graduates need a broad scientific basis and specialist technical know-how and have to be able to build bridges between scientific engineering and society. The department sees the future mechanical engineer as a science-oriented designer and a design/application-oriented researcher, capable of looking beyond the boundaries of disciplines, society and countries.

Mechanical Engineering studies the analysis and synthesis of structures, machines, devices, systems, and processes that accomplish a desired objective in a safe, ethical, and sustainable fashion. Modern mechanical engineering is characterized by increasing multi-disciplinarity, overlapping with life sciences, electrical and chemical engineering, and other domains. The collaborating technical universities in the Netherlands as well as ABED[1], OECD[2], and ASME[3] agreed that the general learning goals of mechanical engineering programmes should cover science (mathematics, physics and thermodynamics), engineering (materials, solid and fluid mechanics, dynamics), and design (specifications, synthesis, modelling and optimisation, manufacturing, evaluation).

Bachelor's programme
The objective of the bachelor's programme is to serve as a solid basis in specific engineering domains, enabling further education at a master's level. The bachelor's curriculum is made up of three key components: basic science (mathematics, physics, and thermodynamics), engineering courses (solid and fluid mechanics, dynamics, control), integrating design projects. The objective is translated into ten intended learning outcomes (ILOs; Appendix 2), which are closely related to the Criteria for Academic Bachelor's Curricula, the so-called Meijers criteria[4].
The panel established that the ILOs are formulated in line with the mission and that they sufficiently indicate what could be expected from programmes at a bachelor's level. It also ascertained that the ILOs meet the internationally accepted description for academic bachelor's programmes, the Dublin

[1] ABET – Criteria for accrediting engineering programs
[2] OECD – A tuning –HELO conceptual framework of expected/desired learning outcomes in engineering
[3] ASME – An Environmental Scan for ASME and the Global Summit on the Future of Mechanical Engineering.
[4] https://www.ram.ewi.utwente.nl/embedded2017/doc/Meijers_summarised.pdf

descriptors. The ILOs are in line with the ABET, OECD and ASME requirements. The panel finds the content, level and orientation of the ILOs to be straightforward; they sufficiently demonstrate their fit with the professional field. There is some distinction between the ILOs of the bachelor's and the master's programmes that indicates the difference in level to be achieved. However, the panel thinks that the ILOs are formulated on a rather general level, and give limited information about the domain. In its view, the ILOs could also apply to other engineering programmes. This is partly due to the structure of the TU/e bachelor college format with general skills and electives. The panel recommends making them more specific for the mechanical engineering programme.

Master's programme
The master's programme is structured to help the students mature into independent engineers or researchers. The objective of the programme to deliver mechanical engineers who are also science-oriented designers and design-oriented researchers is translated into ten intended learning outcomes (ILOs; Appendix 2). The panel established that the ILOs are formulated in line with the mission and that they sufficiently indicate what could be expected from programmes at a master's level. It also ascertained that the ILOs meet the internationally accepted description for academic master's programmes, the Dublin descriptors, which are elaborated for engineering programmes into the 4TU (Meijers) criteria[5]. They are also in line with the ABET, OECD and ASME requirements. The panel finds the content, level and orientation of the ILOs to be straightforward; it is sufficiently demonstrated that they reflect the professional field. There is some distinction between the ILOs of the bachelor's and master's programmes, indicating the difference in level to be achieved. The ILOs are formulated rather generally, however, and could be defined more specifically and tailored to the programme. In the panel's view, the ILOs could also apply to other engineering programmes. It recommends making them specific for the mechanical engineering programme.

Considerations
The panel concluded that the ILOs meet the Dutch qualifications framework. They sufficiently indicate the academic bachelor's or master's level, respectively. The panel finds the content, level and orientation of the ILOs to be straightforward; it is sufficiently demonstrated that they have an academic level and reflect the professional field, which is assured by the alignment with the requirements of the professional engineering organisations ABET and ASME.

There is some distinction between the ILOs of the bachelor's and the master's programmes, indicating the difference in level to be achieved. The ILOs are formulated rather generally, however, and could be defined more specifically and tailored to the programme. The panel recommends making them more specific for the mechanical engineering programme. They are specific enough to fulfil the requirements for standard 1, though.

Conclusion
Bachelor's programme Mechanical Engineering: the panel assesses Standard 1 as satisfactory

Master's programme Mechanical Engineering: the panel assesses Standard 1 as satisfactory.

Standard 2: Teaching-learning environment
The curriculum, the teaching-learning environment and the quality of the teaching staff enable the incoming students to achieve the intended learning outcomes.

Findings
Bachelor programme
The bachelor programme (180 EC) is structured according to the TU/e Bachelor College format and contains 30 EC of basic courses, 90 EC of major courses, including the Bachelor Final Project (BFP), and an elective space (60 EC), including 45 EC of electives and a USE trajectory of 15 EC (selection

[5] https://www.ram.ewi.utwente.nl/embedded2017/doc/Meijers_summarised.pdf

of courses linking technology to User, Society, Enterprise). The basic and major courses are mandatory.

The TU/e-wide basic courses are Calculus, Applied Physical Sciences, Data Analytics for Engineers, USE Basic, Engineering Design and Professional Skills. The training and assessment of the skills concerned are distributed over several major courses, mostly in the Design-Based Learning projects, and the BFP. Theory and application are combined in the major courses, and the department's specialisations are represented in the learning lines: Materials & Mechanics, Energy & Flow, and Systems, Dynamics & Control. Along with these three disciplinary learning lines, the programme distinguishes a design skills and mathematical skills learning line. The panel finds this structure coherent and transparent and appreciates the clear learning lines indicated.

In addition to the basic USE course in the first year, students are obliged to choose a sequence of three USE courses (15 EC) to foster their development as engineers of the future. In the elective space, they can broaden or deepen their knowledge. They can either choose electives from their own department or explore courses from a different department or major. The BFP is an individual project in which the students apply their acquired knowledge and skills in a research or design assignment.

The teaching method in most courses is a combination of plenary frontal lecturing and guided self-study or instruction. The bachelor curriculum contains six Design-Based Learning projects, connected to the major courses. Design-Based Learning (DBL) is a student-centred, problem-based, learning-inspired method in which students work on a problem in groups of six to ten. It mostly involves open-ended projects that require a hands-on approach. The students apply previously acquired or new theoretical information and skills to find a solution to the problem or question presented. During a DBL project, they also develop their professional skills. Each DBL group has a tutor (usually a master-level student), and each DBL project has a case coordinator. An overall DBL coordinator then manages the whole DBL trajectory. Part of the master programme is a tutoring and coaching course (2.5 EC). Almost all master students (there are some exceptions) are trained as tutors and act as a tutor for a DBL project. Trained master students can then request more DBL tutoring on a paid basis. Both the bachelor and the master students reported being satisfied with this system to the panel. The master students find the training and the experience useful for their development, and their performance as a tutor is also formally assessed.

Throughout the bachelor programme students receive individual coaching from their personal study coach on the development of their professional identity and the corresponding options available to them. The coaches help the students with the selection of electives.

During the site visit the panel got a good impression of the DBL projects and how they are implemented in the programme. It found them to be very well developed, managed and implemented. The whole bachelor programme has a clear structure with well-developed learning lines and a close connection to research. The panel also appreciated the attention paid to the development of User, Society and Engineering competences in the USE line. Students receive a solid basis of scientific knowledge, combined with the development of general engineering soft skills and group work, and have enough possibilities to choose electives and build their own profile.

The self-evaluation report describes an intensive continuous improvement process. The panel was impressed by the efforts of the programme to continuously evaluate student yield, course content and teaching staff qualifications. It shows a self-learning organisation continuously trying to improve its programme.

Master programme
The master programme comprises core courses (20 EC), specialisation courses (20 EC), professional skills courses (5 EC), individual space (15 EC), an internship (15 EC), and a graduation project (45 EC). It offers the following specialisations: Polymer Technology, Mechanics of Materials, Micro Systems, Multiphase and Reactive Flows, Energy Technology & Fluid Dynamics, Dynamics & Control,

and Control Systems Technology. Most courses are taken in the first year, and the internship and graduation project fill the second year. For the core courses students choose four courses out of twelve; for the specialisation courses, students choose courses worth 20 EC out of a list of 27 specialisation electives, in consultation with their mentor. Each student has to pass two professional skills courses: Career Development and either Tutoring and Coaching or Teamwork & Academic Writing. The students following the Tutoring and Coaching course are involved in the DBL projects of the bachelor students.

The individual space can be used in various ways, to deepen or widen knowledge with additional courses, to extend the internship, to make up a deficiency with advanced bachelor courses or to study a foreign language.

The internship can be extended to 20 EC and provides experience in a real-life working environment. Most master students go abroad for their internship to another university, a research institute or a company. The students are responsible themselves for the choice of their internship, but they discuss it with their mentor, who has a list of topics and places for internships. A teaching staff member is both supervisor and assessor of the internship, making use of an assessment form with clear criteria. It is possible for a student to fail the internship, but in general a supervisor should act at an early stage before the student is failing the company.

For the graduation thesis, students choose a topic related to the research in the departments. To ensure that all master students receive high-quality supervision, the departmental board aims to match the number of master students allocated to each research group with the capacity of the group and has developed a procedure (Master Allocation Procedure, MAP) for this allocation. The procedure includes a motivation letter from the students. So far, the MAP has been able to place 85% of students in the group of their first choice. Students have no major problems with the MAP procedure; they acknowledge that they do not like it when they are not placed in the group of their first choice, but otherwise they find good supervision more important. The panel had prepared in advance some questions concerning the MAP procedure, but appreciated the practical solution found and agreed with the students' evaluation that good supervision is most important.

Students and study yield
The study yields in both the bachelor programme and the master programme are not very high, but they have improved slightly over the last few years. The panel also learnt during the site visit that the programme management is proactively monitoring the progress of students and takes measures when necessary to remove impediments.

At the beginning of the 2014/2015 academic year, the department launched a comprehensive plan to improve the study yields of the master programme. This plan (MMA: Marking, Monitoring and Action) comprises a series of coaching and guiding activities for the academic advisor, an internship contract to ensure timely completion of the internship, and measures to limit the time spent on the graduation project. The MMA measure includes dividing the graduation project into a preparation phase and a project phase, both limited in duration. The panel endorses this plan and is in particular very positive about the measures to limit the duration of the graduation phase.

Teaching staff
An overview of the teaching load in the bachelor and master programme is provided in the self-evaluation report. The student-staff ratio has increased significantly in recent years due to increasing student numbers and a decline in the teaching staff involved. The reported student to staff ratio is 25 per fte. Various measures have been taken by the board to control and limit this ratio by increasing staff numbers, spreading the workload by allocating students (MAP) and investigating a potential "numerus fixus" for first-year students starting in 2019-2020. The numerus fixus is, however, not yet been approved by the Ministry of Education for the coming years.

Of the teaching staff, 75% holds a University Teaching Qualification, and the rest are currently working on their certification, so a further increase of this percentage is expected. Students appreciate the teaching quality of the staff. The panel appreciated the involvement in and enthusiasm for teaching and student guidance of the bachelor teaching staff in particular. Overall, the panel thinks that the quality of the teaching staff is good.

Considerations
The panel found the curriculum to be well developed, managed and implemented, and there is a good alignment between the ILOs and the curriculum. It is very positive about the DBL projects and the learning lines that structure the curriculum. The whole bachelor programme has a clear structure with well-developed learning lines and a close connection to research. Students receive a solid basis in scientific knowledge, combined with the development of soft skills and group work, and have enough possibilities to choose electives and build their own profile. The panel also appreciates the attention paid to the development of User, Society and Engineering competences in the USE line.

The structure of the curriculum of the master programme is comparable to that of other engineering master programmes. The sound, thorough curriculum enables the students to achieve the ILOs. The panel appreciates the close connection to the research groups which enables the students to achieve a high level in research.

The panel endorses the MMA plan to improve the study yields and was impressed by the continuous efforts to evaluate and improve the bachelor programme.

The quantity and the quality of the teaching staff are good.

Conclusion
Bachelor's programme Mechanical Engineering: the panel assesses Standard 2 as good.

Master's programme Mechanical Engineering: the panel assesses Standard 2 as good.

Standard 3: Student assessment
The programme has an adequate system of student assessment in place.

Findings
Assessment policy
The Department of Mechanical Engineering developed its own assessment policy, based on the TU/e framework. This policy applies to all programmes and describes the instruments, procedures, and criteria for examinations, group work and individual projects. It also sets out the composition and tasks of the Examination Committee and Assessment Committee, as well as the fraud and plagiarism policies. There are Programme and Examination Regulations concerning assessors, marking and quality assurance for examinations written down for each programme. The Assessment Committee is a sub-committee of the Examination Committee. It has the task to monitor the quality of the course assessments, internships and thesis work. The findings of the Assessment Committee are reported to the programme director. Students and teachers find the assessment system, the assessment methods and the instruments to be transparent. The teachers are aware of the procedures and report that they are using them. The students mentioned during the site visit that the assessment methods are clear to them. The panel had a look at the assessment plans. It established that the assessment system guarantees the reliability and validity of the exams and assessments.

Assessment methods
In general, the assessment of courses involves a written exam at the end. In the master's programme, assignments or oral examinations (or a combination of the two) are commonly used. In the first year of the bachelor's programme, interim testing is mandatory to provide students with

feedback on their progress. Interim tests can take many forms such as a written test, assignments, projects, quizzes, presentations, or reports. The DBL courses are assessed through a combination of individual assessment and group work. Individual assessment is based on the student's individual performance during the group sessions. The performance is assessed by the tutor using a rubric, in combination with a peer review. Group work is assessed by the course coordinator, based on the required final product, report, and/or presentation. Rubrics are used to facilitate uniform assessment.

The Bachelor Final Project is assessed by at least one authorized examiner, using a rubric based on five criteria: planning and organisation, independence and professional behaviour, capacity of analysis and reflection, written report, and colloquium.

The internship in the master's programme is assessed by a supervisor, who is also an authorised examiner. The role of the supervisor is to assure the quality of the work performed during the internship and to grade it. The final assessment by the supervisor is based on an external assessment by a company supervisor and a written report.

The assessment of the master graduation project is performed by a Graduation Committee. The student delivers a thesis report, gives a presentation and defends the thesis in front of the Graduation Committee. The committee consists of at least three faculty members from TU/e or another university, is chaired by a full or an associate professor of the research group in which the student has carried out the graduation project, and includes at least one member from a different research group (or another department / university). A standard assessment form is used to grade the thesis.

Examination Committee
During the site visit the panel had a meeting with the Examination Committee about its responsibilities and the way the quality of assessment is assured. It ascertained that the Examination Committee is adequately performing its legal duties and responsibilities. The assessment system and policy seem to be quite well developed and implemented, although the panel could not get a clear picture of the way the Assessment Committee performs its tasks. The panel advises the Examination Committee to act more proactively and take ownership of the quality assurance of the assessments.

Considerations
The bachelor and master programme Mechanical Engineering have an adequate quality assurance system. There are procedures in place to assure the validity and reliability of the tests. The panel concluded that the examinations, tests and thesis assessment are transparent, valid and reliable. It also established that there are adequate assessment forms in place. The Examination Committee is adequately performing its legal duties and responsibilities.

Conclusion
Bachelor's programme Mechanical Engineering: the panel assesses Standard 3 as satisfactory.

Master's programme Mechanical Engineering: the panel assesses Standard 3 as satisfactory.

Standard 4: Achieved learning outcomes
The programme demonstrates that the intended learning outcomes are achieved.

Findings
The panel studied a selection of 15 bachelor final projects and 15 master theses to assess whether the graduates achieve the ILOs. It found both the bachelor final projects and the master theses to be of a high level overall.

The BFP reports showed that the bachelor students are qualified in the domain of engineering science and technology and are able to conduct research and design under supervision. They demonstrated a scientific approach to problems and ideas, based on current knowledge. The bachelor programme

prepares the students for continuing their studies in a master programme. The alumni of the bachelor programme felt well prepared for the master programme. Almost no bachelor graduate enters the labour market directly after graduation.

The panel also concluded that the master graduates achieve the level that can be expected of them. It studied a selection of theses with an appropriate mix of higher grades and lower grades. It would have graded most theses slightly higher than the graduation committee. It considered it very positive that the thesis topics are well linked to industry. The assessment of the theses demonstrated a careful check of the outcomes. The theses showed that the graduates are able to conduct research and design independently, have a scientific approach to complex problems and ideas, and have the ability to seek new potential applications, taking the social context into consideration. The theses showed an advanced level of knowledge in a specialised field, systematic understanding of the key aspects and concepts in mechanical engineering, and the ability to integrate theory and practice.

The Mechanical Engineering Department of TU/e conducted a survey among employers of its graduates. The results of this survey underline the conclusion that the graduates of the master programme are well prepared for the professional field. In 2017-2018 several alumni surveys were conducted on a national level as well as by the TU/e. The outcomes of these surveys confirmed that the graduates had a good basis for the job market. The alumni are very positive about the quality of the master programme and feel well prepared for either a PhD programme or a career in industry.

Considerations
The panel concludes that graduates of the bachelor programme Mechanical Engineering have achieved the ILOs. It found the level of the BFP reports to be good. The graduates of the bachelor programme are well prepared for continuing their study in a master's programme.

The panel concludes that graduates of the master programme Mechanical Engineering have achieved the ILOs. It found the level of the master theses to be very good and would have graded most theses higher than the graduation committee. The graduates are well prepared for continuing in a PhD programme or a career in industry.

Conclusion
Bachelor's programme Mechanical Engineering: the panel assesses Standard 4 as good.

Master's programme Mechanical Engineering: the panel assesses Standard 4 as good.

GENERAL CONCLUSION

The panel assesses standards 1 and 3 of the bachelor programme as satisfactory and standards 2 and 4 as good. It was very positive about the teaching-learning environment offered to the students. The DBL and the learning lines in the curriculum build an attractive programme for students, preparing them very well for continuing their studies in a master programme. The panel was also positive about the level achieved by the graduates. Following the NVAO decision rules, the panel's general conclusion is that the programme is assessed as good.

The panel assesses standards 1 and 3 of the master programme as satisfactory and standard 2 and 4 as good. It was very positive about the level achieved by the master graduates. Following the NVAO decision rules, the panel's general conclusion is that the programme is assessed as satisfactory.

Conclusion
The panel assesses the *bachelor's programme Mechanical Engineering* as good.

The panel assesses the *master's programme Mechanical Engineering* as good.

APPENDICES

APPENDIX 1: DOMAIN-SPECIFIC FRAMEWORK OF REFERENCE

Introduction
Mechanical Engineering studies the analysis and synthesis of structures, machines, devices, systems and processes that accomplish a desired objective in a safe, ethical and sustainable fashion. Mechanical engineers therefore improve the quality of life, address societal challenges, and improve industrial competitiveness. No profession unleashes the spirit of innovation like engineering. From research to realworld applications, engineers constantly discover how to improve our lives by creating bold new solutions that connect science to life in unexpected, forward-thinking ways. There is great variety in fields of application: from small to large scale, static and dynamic, from deep-sea to space, to name a few. Modern mechanical engineering is characterized by increasing multidisciplinarity, i.e. overlap with life sciences, electrical and chemical engineering etc. This necessitates a systems approach in which the various fields of expertise reinforce one another, giving rise to world leading mechatronics, nanomanufacturing, robotics, precision agriculture, shipbuilding and more. The Netherlands stands out in this respect, which, along with a strong entrepreneurial spirit, partly explains its innovative power.

Curriculum
Between the technical universities, active collaboration and exchange of students and faculty takes place. The three curricula in Mechanical Engineering in the Netherlands, at Delft University of Technology, Eindhoven University of Technology and University of Twente, comply with the definitions in ABET, OECD and ASME. The curriculum is based on a solid scientific foundation, deep engineering knowledge, and agile engineering design skills. A variety of modalities is used, such as courses and projects, designed to mutually stimulate each other; i.e. the knowledge from the courses is to be applied in the projects, and conversely, in their design projects students will experience the need for and utility of basic knowledge and engineering methodology.
Overall learning goals cover science (mathematics, physics and thermodynamics), engineering (materials, solid and fluid mechanics, dynamics), and design (specifications, synthesis, modelling and optimization, manufacturing, evaluation).

The Bachelor curriculum is composed of three key components:
1. Basic science (mathematics, physics, thermodynamics)
2. Engineering courses (solid and fluid mechanics, dynamics, control)
3. Design projects (integration of the above analysis tools in a synthesis-oriented group effort, along with dedicated knowledge acquisition and soft skill training). Projects are structured accordingly, with integration of design specification, synthesis, modelling and optimization, manufacturing, evaluation and presentation techniques.

The Bachelor includes a one-semester Minor of choice or elective programme plus a Bachelor end project, i.e. a research or design project performed in small groups or individually.

The Master curriculum is composed of one year of courses in a MSc track, plus a second year of internship (optional in some cases) and graduation project including a literature study, in which students mature to independent engineers or researchers. In some cases (part of) a graduation study is done in a company or another lab (abroad). In several cases a graduation study results in a scientific publication.

Criteria for a Mechanical Engineering programme
The engineering field requires an understanding of core concepts including solid and fluid kinematics, thermodynamics, control, materials science, and structural analysis. Mechanical engineers use these core principles along with tools like computer-aided engineering and product lifecycle management to design and analyse manufacturing plants, industrial equipment and machinery, heating and cooling systems, transport systems, aircraft, watercraft, robotics, medical devices and more. The field has continually evolved to incorporate advancements in technology, and mechanical engineers

today are pursuing developments in such fields as composites, mechatronics, additive and intelligent manufacturing and nanotechnology.

The fundamental subjects of mechanical engineering include:
- Statics and dynamics
- Solid mechanics and strength of materials
- Materials engineering
- Mathematics including calculus, differential equations and linear algebra
- Thermodynamics, heat transfer, energy conversion
- Fluid mechanics and dynamics
- Mechanism design (including kinematics and dynamics)
- Manufacturing engineering (technology and processes)
- Design engineering (including CAD/CAM)

Mechanical engineers are also expected to understand and be able to apply basic concepts from chemistry, physics, chemical engineering, civil engineering and electrical engineering. Most mechanical engineering programmes include multiple semesters of calculus, as well as advanced mathematical concepts including differential equations, partial differential equations, linear algebra, abstract algebra, and differential geometry, among others.

The domain specific requirements are translated into ILOs of the programme.

APPENDIX 2: INTENDED LEARNING OUTCOMES

Bachelor's programme Mechanical Engineering
Bachelor of Science graduates Mechanical Engineering:
1. are qualified to degree level within the domain of engineering science and technology,
2. are competent in the relevant domain-specific discipline(s) at the level of a Bachelor of Science, (as specified in the domain specific frame of reference),
3. are able to conduct research and design under supervision,
4. are aware of the significance of other disciplines,
5. take a scientific approach to non-complex problems and ideas, based on current knowledge,
6. possess intellectual skills that enable them to reflect critically, reason and form opinions under supervision,
7. are good at communicating the results of their learning, thinking, acts and decision-making processes,
8. can plan and implement their activities,
9. are aware of the temporal and societal contexts of science and technology (comprehension and analysis),
10. in addition to a recognizable domain-specific profile, possess a sufficiently broad basis to be able to work or collaborate in an interdisciplinary and multidisciplinary context.
Here, multidisciplinary means focusing on other relevant disciplines needed to solve the design or research problem in question.

Master's programme Mechanical Engineering
A Mechanical Engineering Master of Science graduate:
1. is qualified to degree level within the domain of 'science engineering & technology'
2. is competent in the relevant domain-specific discipline(s), namely Mechanical Engineering
3. is able to conduct research and design independently,
4. has the ability and attitude to include other disciplines in their research, where necessary,
5. has a scientific approach to complex problems and ideas,
6. possesses intellectual skills that enable them to reflect critically, reason and form opinions,
7. has the ability to communicate the results of their learning, thinking and decision-making processes at an international level,
8. is aware of the temporal and social context of science and technology (comprehension and analysis) and can integrate this in their scientific work,
9. in addition to a recognizable domain-specific profile, possess a sufficiently broad basis to be able to work in an interdisciplinary and multidisciplinary context. In this context, multidisciplinary means being focused on other relevant disciplines needed to solve the design or research problem in question,
10. has the ability and attitude to seek new potential applications, taking the social context into consideration.

APPENDIX 3: OVERVIEW OF THE CURRICULUM

Bachelor's programme Mechanical Engineering

	Q1.1	Q1.2	Q1.3	Q1.4
2016-2017	2WBBo Calculus (5 EC)	3NCBo Applied Physical Sciences flows (5 EC)	2IABo Data Analytics for engineers (5 EC)	0SABo USE: ethics and history of technology (5 EC)
	4RAoo Mechanics (5 EC)	4DAoo Dynamics (5 EC)	4RA10 Introduction transport phenomena (5 EC)	4MAoo Structure and properties of materials (5 EC)
	4GAoo Introduction Mechanical Engineering and truss structures(5 EC)	Elective (5 EC)	4GA40 Peristaltic pump (5 EC)	Elective(5 EC)
	Q2.1	**Q2.2**	**Q2.3**	**Q2.4**
2017-2018	4WBBo Engineering design (5 EC)	4EBoo Thermodynamics (5 EC)	4MBoo Solid Mechanics (5 EC)	4PBoo Heat and flow (5 EC)
	4CBoo Signals & systems (5 EC)	4DBoo Dynamics & control of mechanical engineering (5 EC)	4GB10 Combustion engine (5 EC)	4GB20 Robot-arm (5 EC)
	Elective (5 EC)	Elective (5 EC)	Elective (5 EC)	Elective (5 EC)
	Q3.1	**Q3.2**	**Q3.3**	**Q3.4**
2018-2019	4MC10 Computational Mechanics (5 EC)	4CC30 Design principles (2.5 EC)	Elective (5 EC)	Elective (5 EC)
		4DC10 Analysis of manufacturing systems (2.5 EC)		
	4GCoo Computer Aided Engineering (5 EC)	4GC10 Mechanical design project (5 EC)	Elective (5 EC)	Elective (5 EC)
	Elective (5 EC)	Elective (5 EC)	4WCoo Bachelor Final project (10EC)	

Master's programme Mechanical Engineering

Core program: students choose 4 out of 12 core courses.

Q1	Q2	Q3	Q4
4CM00 Control Engineering (5 EC)	4BM20 Experimentation for Mechanical Engineering (5 EC)	4CM00 Control Engineering (5 EC)	4CM50 Applications of Design Principles (5 EC)
4BM00 Advanced Engineering Mathematics (5 EC)	4DM10 Multibody and Non-linear Dynamics (5 EC)	4DM20 Engineering Optimization (5 EC)	4MM50 Fracture Mechanics - Theory and Application (5 EC)
4BM60 Interfacial Transport Phenomena in Engineering Flows (5 EC)	4EM70 Sustainable Energy Sources (5 EC)	4EM30 Scientific Computing for Polymer Mechanics (5 EC)	4UM00 Microfabrication Methods (5 EC)
4UM00 Microfabrication Methods (5 EC)	4MM10 Advanced Computational Continuum Mechanics (5 EC)		

Two of the core courses (4UM00 and 4CM00) are offered twice a year, due to limited lab capacity (4UM00) or high interest of students (4CM00).

Specialization courses: students choose 20 EC (4-6 courses) out of 27 specialization courses. Number of courses depends on size of course.

Q1	Q2	Q3	Q4
4BM10 Hydraulic Turbomachines (5 EC)	4BM30 Modelling Combustion (5 EC)	4CM30 Supervisory Control (5 EC)	4BM40 Optical Diagnostics for Combustion and Fluid Flow (5 EC)
4CM10 System Theory Control (5 EC)	4CM20 Hybrid Systems and Control (5 EC)	4CM40 Physical Modelling (5 EC)	4BM50 Introduction to Petroleum Production (2.5 EC)
4DM00 Structural Dynamics and Vibro-acoustics (5 EC)	4CM70 Integrated Systems Design (5 EC)	4DM30 Non-linear Control (5 EC)	4CM60 Advanced Motion Control (5 EC)
4LM10 Polymer Components in High Performance Applications (2.5 EC)	4EM10 Gas dynamics (5 EC)	4EM50 Thermal Energy Storage (2.5 EC)	4DM40 Modelling and Control of Manufacturing Systems (5 EC)
4MM00 Composite and Light-weight Materials (5 EC)	4EM40 Heat and Flow in Microsystems (5 EC)	4LM30 Multiscale Modelling for Polymer Mechanics (5 EC)	4DM50 Dynamics and Control of Cooperation (2.5 EC)
	4LM20 Polymer Processing (5 EC)	4RM00 Introduction to Computational Fluid Dynamics (5 EC)	4DM60 Control of Distributed Parameter Systems (2.5 EC)
	4MM20 Computational and Experimental Micro-Mechanics (5 EC)	4UM10 Microfluidics put-to-work (5 EC)	4EM60 Advanced Discretization Techniques (5 EC)
			4LM50 Rheology (5 EC)

Professional skills courses

Q1	Q2	Q3	Q4
4WM00 Coaching and tutoring (2.5 EC)	4WM00 Coaching and tutoring (2.5 EC)	4WM00 Coaching and tutoring (2.5 EC)	4WM00 Coaching and tutoring (2.5 EC)
4WM10 Career development (2.5 EC)	4WM10 Career development (2.5 EC)	4WM10 Career development (2.5 EC)	4WM10 Career development (2.5 EC)
	4WM50 Teamwork and Academic Writing (2.5 EC)	4WM50 Teamwork and Academic Writing (2.5 EC)	

APPENDIX 4: PROGRAMME OF THE SITE VISIT

Tuesday 11 December 2018

Time	Delegations	
10.30-11.15	Programme Management Mechanical Engineering	Graduate Program Director, Programme Coordinator, Chair programme committee, Member curriculum committee
11.20-12.00	Bachelor students Mechanical Engineering	Two 1st year students, two second year students, two third year students
12.00 - 13.00	Labtour	
13.00-13.45	Master students and alumni Mechanical Engineering	Three master students, four alumni
13.50-14.35	Lecturers Bachelor Mechanical Engineering	
14.45-15.30	Lecturers Master Mechanical Engineering	
15.30-16.00	Examination committee Mechanical Engineering	
16.00-18.00	Drafting preliminary conclusions Mechanical Engineering	

Wednesday 12 December 2018

Time	Delegations	
9.30-10.15	Programme Management Automotive Technology	Graduate Program Director, Adjunct Program Director, Chair program committee
10.15-11.00	Master students Automotive Technology and alumni	Four master students and three alumni
11.00-11.30	Lecturers Automotive Technology	
12.30-13.00	Examination committee Automotive Technology	
13.30-14.15	Formal management Mechanical Engineering + Automotive Technology	Dean, Graduate Programme Director ME, Graduate Program Director AT
14.15 -16.00	Drafting preliminary conclusions	
16.00	Feedback to management, staff and students concerning the bachelor and master programme Mechanical Engineering and the master programme Automotive Technology	

APPENDIX 5: THESES AND DOCUMENTS STUDIED BY THE PANEL

Prior to the site visit, the panel studied 15 theses of the bachelor's programme Mechanical Engineering and 15 theses of the master's programme Mechanical Engineering. Information on the selected theses is available from QANU upon request.

During the site visit, the panel studied, among other things, the following documents (partly as hard copies, partly via the institute's electronic learning environment):

- Annual Report Education 2015-2016,2016-2017
- Programme Committee Minutes 2017-2018
- Programme and Examination Regulations 2018-2019
- Quality Assurance Plan 2018-2019
- Result Form Internship 2018
- Examination Committee Minutes 2017-2018
- Annual Report Bachelor College 2016
- DATA VSNU bachelor Werktuigbouwkunde
- Management Report Master Mechanical Engineering 2017-2018
- Toetsbeleid Faculteit WTB
- Tue Alumni Monitor 2017
- Tue Education Fraude Policy
- Alumni Survey Mechanical Engineering 2018
- MAP procedure 2018
- Employer Survey MSc Mechanical Engineering