# INDUSTRIAL ENGINEERING AND MANAGEMENT

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This report was finalised on the 6$^{th}$ of March, 2017

# REPORT ON THE BACHELOR'S PROGRAMME TECHNISCHE BEDRIJFSKUNDE AND THE MASTER'S PROGRAMME INDUSTRIAL ENGINEERING AND MANAGEMENT OF UNIVERSITY OF GRONINGEN

This report takes the NVAO's Assessment Framework for Limited Programme Assessments as a starting point (19 December 2014).

## ADMINISTRATIVE DATA REGARDING THE PROGRAMMES

**Bachelor's programme Technische bedrijfskunde**

| | |
|---|---|
| Name of the programme: | Technische bedrijfskunde |
| CROHO number: | 56994 |
| Level of the programme: | bachelor's |
| Orientation of the programme: | academic |
| Number of credits: | 180 EC |
| Specialisations or tracks: | Production Technology and Logistics<br>Product and Process Technology |
| Location(s): | Groningen |
| Mode(s) of study: | full time |
| Language of instruction: | English |
| Expiration of accreditation: | 31-12-2019 |

**Master's programme** Industrial Engineering and Management

| | |
|---|---|
| Name of the programme: | Industrial Engineering and Management |
| CROHO number: | 60029 |
| Level of the programme: | master's |
| Orientation of the programme: | academic |
| Number of credits: | 120 EC |
| Specialisations or tracks: | Production Technology and Logistics<br>Product and Process Technology |
| Location(s): | Groningen |
| Mode(s) of study: | full time |
| Language of instruction: | English |
| Expiration of accreditation: | 31-12-2019 |

The visit of the assessment panel Industrial Engineering and Management to the Faculty of Mathematics and Natural Sciences (since 1st of February 2017: The Faculty of Science and Engineering, which name has been adopted throughout this report) of University of Groningen took place on the 14th and 15th of November.

## ADMINISTRATIVE DATA REGARDING THE INSTITUTION

| | |
|---|---|
| Name of the institution: | University of Groningen |
| Status of the institution: | legal body providing higher education |
| Result institutional quality assurance assessment: | positive |

# COMPOSITION OF THE ASSESSMENT PANEL

The panel that assessed the bachelor's programme Technische bedrijfskunde and the master's programme Industrial Engineering and Management consisted of:

- Prof.dr.ir. R.E.C.M. van der Heijden, Radboud University Nijmegen, chair
- Prof.dr. H.M.C. Eijkelhof, Utrecht University
- Prof.dr. E. Meijer, Eindhoven University of Technology
- Dr. M. Nip, Raw Materials Procurement, Tata Steel Group
- Dr. H. Ramirez Estay, Université de Franche-Comte and FEMTO-ST, Besançon, France
- S. Vreriks, University Twente, student member

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

Appendix 1 contains the curricula vitae of the panel members.

# WORKING METHOD OF THE ASSESSMENT PANEL

*Cluster*

The bachelor's programme Technische bedrijfskunde and the master's programme Industrial Engineering and Management at the University of Groningen were assessed as part of the cluster Industrial Engineering and Management and Systems Engineering, Policy Analysis & Management. The cluster Industrial Engineering and Management and Systems Engineering, Policy Analysis & Management encompasses eleven programmes at four universities: Delft University of Technology (hereafter: TU Delft), University of Groningen, University of Twente and Eindhoven University of Technology. TU Delft served as first point of contact and secretary on behalf of all four universities. Dr. E. Schröder, project manager at QANU, assisted the cluster in organisational and practical matters.

The project manager approached independent panel members based on the programmes' recommendations, taking into account specialised tracks at the four institutions. The NVAO approved the panel composition on the 10th of October 2016. The cluster panel consisted of the following members:

- Prof.dr.ir. Rob van der Heijden, Radboud University Nijmegen [chair];
- Prof.dr. Harrie Eijkelhof, Utrecht University;
- Prof.dr. Erik Demeulemeester, KU Leuven, Belgium;
- Prof.dr. Jan Kratzer, Technische Universität Berlin, Germany;
- Prof.dr. Arthur Petersen, University College London, United Kingdom;
- Prof.dr. Marcel Veenswijk, VU University Amsterdam;
- Prof.dr. Hens Runhaar, Wageningen University;
- Prof.dr. Emmo Meijer, Eindhoven University of Technology;
- Dr. Margriet Nip, Tata Steel;
- Dr. Hector Ramirez Estay, Université de Franche-Comté, France;
- Maarten van Ruitenbeek BSc, University of Groningen [student member];
- Sofie Vreriks BSc, University of Twente [student member];

Prof.dr.ir. Rob van der Heijden acted as panel chair during all four site visits. Additionally, prof.dr. Harrie Eijkelhof, an education expert with a long-standing academic career in teaching in science, agreed to partake in all four assessments. Two QANU secretaries were appointed to assist the panel during site visits: QANU project manager dr. Els Schröder and dr. Barbara van Balen, independent NVAO-certified secretary. A calibration meeting took place on the 15th of December 2016 between prof.dr.ir. Van der Heijden, prof.dr. Eijkelhof and both secretaries to attune the panels' findings to further assure consistency of assessment within the cluster.

*Site visit University of Groningen*
In preparation for the assessment, the management provided a critical reflection for the bachelor's and master's programmes. In these critical reflections, the management described the current state of affairs and provided useful information for the assessment of its programmes. The project manager checked the report for completeness of information before sending it to the panel members. In consultation with the chair, the secretary selected fifteen bachelor theses and fifteen master theses, covering the full range of marks given. While the master graduation project has recently changed the chair decided to select two recent research projects and two recent design projects as well. The panel, therefore, assessed 19 master graduation projects.

A site visit to the Faculty of Science and Engineering at the University of Groningen took place on the 14$^{th}$ and 15$^{th}$ November 2016 in the presence of five panel members, assisted by an NVAO-certified secretary. The sixth panel member, dr. M. Nip, could not attend the site visit due to illness, but participated in the assessment of the programmes and the theses by email and prepared the assessment in writing. Prior to the site visit, the panel asked the programme to select representative interview partners. It met during the site visit with the programme management, current students, staff, alumni, members of the examination board and members of the programme committee. For the programme of the site visit, see Appendix 5.

The panel also examined relevant study material, assessment forms and additional material during the site visit. This material is listed in Appendix 6. The panel provided students and lecturers the opportunity to meet informally during a consultation hour outside the set interviews. No requests were received for this option. The panels used the final part of the visit for an internal meeting to discuss its findings. The visit was concluded with an oral presentation of the preliminary impressions and general observation by the chair of the panel. This presentation was open to all.

Based on the panel's findings, a draft report was prepared by the secretary. All panel members commented upon the draft report and their comments were implemented accordingly. Subsequently, the programme checked for factual irregularities. Comments by the programme were discussed between secretary and chair and, where necessary, other panel members before finalising the report.

*Decision rules*
In accordance with the NVAO's Assessment framework for limited programme assessments (2014), the panel used the following definitions for the assessment of both the standards and the programme as a whole.

**Generic quality**
The quality that can reasonably be expected in an international perspective from a higher education bachelor's or master's programme.

**Unsatisfactory**
The programme does not meet the current generic quality standards and shows serious shortcomings in several areas.

**Satisfactory**
The programme meets the current generic quality standards and shows an acceptable level across its entire spectrum.

**Good**
The programme systematically surpasses the current generic quality standard.

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

# SUMMARY JUDGEMENT

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

*Bachelor's programme Technische bedrijfskunde*

*Standard 1: Intended learning outcomes*
The bachelor's degree programme Technische bedrijfskunde aims to teach the basic or elementary principles of Industrial Engineering and Management (IEM), needed to perform a thorough problem analysis, draft an appropriate design/redesign, implement and validate technological products, processes and systems in a socio-technological business environment. 70% of the intended learning outcomes and the programme is dedicated to technology and 30% to management. The panel considers it positive that the programme has a distinctive focus on mathematical-technological subjects.

The panel established that the intended learning outcomes are of a sufficient level for a bachelor's degree programme and concluded that the intended learning outcomes meet the Dutch qualifications framework and tie in with the international perspective of the requirements set by the professional field and the discipline. They fit the Domain Specific Framework of Reference developed by the Dutch programmes for Industrial Engineering and Management and they meet the requirements of ABET, the international Accreditation Board for Engineering and Technology. The panel, however, noticed that the difference in level and orientation between the bachelor's programme and the master's programme could be articulated more. The panel suggests to formulate the intended learning outcomes in such a way that they could be used in a more operational approach to further articulate the existing differences in level, profile and orientation between the bachelor's and master's programmes.

*Standard 2: Teaching-learning environment*
The bachelor's curriculum has an engineering design approach with a strong focus on the technical and mathematical aspects. After a shared first year, students choose a track out of two options: Production Technology and Logistics (PTL) or Product and Process Technology (PPT). The first year of the curriculum focuses on general engineering design skills and technical and mathematical aspects of artefacts. In the second and third year, in addition to track specific courses, students follow shared core IEM course units, usually in the field of management and business design. The final step in the bachelor's degree programme is the bachelor's thesis specified as the integration project. The students are supposed to integrate all - multidisciplinary - knowledge and competences learned during their bachelor's studies in this project.

The content and structure of the programme are in line with what can be expected of the level and orientation of a bachelor's programme. It was clear to the panel that the teachers bring their current research into the programme and that a positive exchange between research and teaching can be found. The programme also pays sufficient attention to the relation with industry and societally relevant issues. The programme enables its students to meet the intended learning outcomes. The panel, however, noticed that it is a rigid programme that leaves limited room for individual choices by students, which is also impeding the programme's ambitions regarding further internationalisation. The panel advises to bring more flexibility in the programme, create room for electives and stimulate students to do part of their studying abroad.

The panel appreciates the introduction of the learning trajectories, which have, together with the intensified cooperation between teachers, contributed to the coherence of the programme. The panel is also very positive about the introduction of learning communities, organising the student-cohorts in teams of 10-15 students, tutored by teaching-assistants. The quality of the teaching staff is good and their efforts to cooperate and fine tune course units are much appreciated by the panel.

*Standard 3: Assessment*
The assessment panel established that the bachelor's programme Technische bedrijfskunde has a well-developed, extensive and fully implemented assessment system in place. The panel appreciates the introduction of a yearly assessment plan and the course unit assessment overviews. The Board of Examiners (BoE) has demonstrated to have complete and thorough insight in all relevant material and to guarantee the quality of the testing and examination. The assessments and tests are regularly checked by the BoE for validity and reliability. The panel was impressed by the way the BoE performs its tasks.

*Standard 4: Achieved learning outcomes*
The panel studied a selection of fifteen bachelor integration projects to assess whether the graduates had achieved the intended learning outcomes. The panel concluded that the bachelor graduates did indeed achieve the level that was expected. The level of the graduation projects concurs with the level that is expected from an academic bachelor programme. The panel established that the bachelor graduates are well prepared for further studies, both for the master's programme Industrial Engineering and Management as well as for adjacent fields of study.

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

*Master's programme Industrial Engineering and Management*

*Standard 1: Intended learning outcomes*
The mission of the master's programme Industrial Engineering and Management is to train engineers who design solutions for IEM-related problems from a strong technological and research perspective. Graduates of the master's programme should be able to understand, analyse, and design/ redesign advanced and complex technological products and processes in a multidisciplinary way. The panel finds it positive that the programme has a distinctive focus on mathematical-technological subjects.

The panel established that the mission of the programme has been translated into intended learning outcomes, which meet the Dutch qualifications framework and tie in with the international perspective of the requirements set by the professional field and the academic discipline. They fit the Domain Specific Framework of Reference developed by the Dutch programmes for Industrial Engineering and Management and they meet the requirements of the international Accreditation Board for Engineering and Technology (ABET).

The panel, however, noticed that the difference in level and orientation between the bachelor's programme and the master's programme could be articulated more. The panel suggests to formulate the intended learning outcomes in such a way that they could be used in a more operational approach to further articulate the existing differences in level, profile and orientation between the bachelor's and master's programmes.

*Standard 2: Teaching-learning environment*
From the start of the master's programme students make a choice for one of the two existing tracks: Production Technology and Logistics (PTL) or Product and Process Technology (PPT). The programme outline in the master's programme is similar for both tracks. The first master year is mainly made up of compulsory courses and electives. The second year consists of a design and a research project and the course Research Methodology. In the research projects, staff members involve students in their current research with the aim to publish together. The design project allows students to show

their competences in designing and cooperating in a multidisciplinary environment, to connect with the industry and to prepare themselves for the labour market.

The panel is positive about the way in which master's students are involved in academic oriented research projects and industry oriented design projects. The students demonstrate being able to perform scientific research while also applying their knowledge and competences in an industrial context. The content and structure of the programme are in line with what can be expected of the level and orientation of a master's programme. The contents and structure of the curriculum enable students to achieve the intended learning outcomes.

*Standard 3: Assessment*
The assessment panel established that the master's programme Industrial Engineering has a very good extensive and fully implemented assessment system. The panel appreciates the introduction of a yearly assessment plan and the course unit assessment overviews. The Board of Examiners (BoE) has shown to have complete insight in all relevant material and to guarantee the quality of the testing and examination. The assessments and tests are regularly checked by the BoE for validity and reliability. The panel was impressed by the way the BoE performs its tasks.

*Standard 4: Achieved learning outcomes*
The panel studied a selection of nineteen master design projects and master's research projects to assess whether the programme's graduates achieved the intended learning outcomes. The panel concluded that they indeed achieved the level that may be expected from a master's graduate. The level of the graduation projects concurs with the level that may be expected from an academic master's programme.

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

The chair and the secretary of the panel hereby declare that all panel members have studied this report and that they agree with the judgements laid down in the report. They confirm that the assessment has been conducted in accordance with the demands relating to independence.

Date: 6th of March, 2017

Prof.dr.ir. R.E.C.M. van der Heijden

dr. B.M. van Balen

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

The bachelor's degree programme Technische bedrijfskunde and the master's degree programme Industrial Engineering and Management are offered by the Faculty of Science and Engineering of the University of Groningen. The programmes were established in 2003 and reaccredited in 2013. The programmes joined – in preparation of this assessment - the already existing IEM cluster of Eindhoven University of Technology, the University of Twente and Delft University of Technology. As a result the assessment and site visit for reaccreditation of the programme has been moved forward from the end of 2018 to the end of 2016. The improvement process started right after the previous programme assessment in 2012, which is, however, relatively recently compared to the current assessment. Therefore, not all results of the improvement are yet visible.

**Standard 1: Intended learning outcomes**
The intended learning outcomes of the programme have been concretised with regard to content, level and orientation; they meet international requirements.

**Explanation**:
As for level and orientation (bachelor's or master's; professional or academic), the intended learning outcomes fit into the Dutch qualifications framework. In addition, they tie in with the international perspective of the requirements currently set by the professional field and the discipline with regard to the contents of the programme. Insofar as is applicable, the intended learning outcomes are in accordance with relevant legislation and regulations.

**Findings**
The programme management defines Industrial Engineering and Management as 'an engineering discipline dealing with engineering problems in which technology/ innovative technology play a central role, but where the broader business context is also of particular interest for the chosen solution.'

The *bachelor's programme* Technische bedrijfskunde aims to teach students basic knowledge and skills in the field of Industrial Engineering and Management (IEM) needed to perform a thorough problem analysis, draft an appropriate design/redesign, implement and validate technological products, processes and systems in a socio-technological business environment. Furthermore, the programme wants to give students an academic training aimed at autonomous, critical and analytical thinking and acting. The programme concentrates on the design of systems with a broad range of different stakeholders. The programme intends to prepare students for an IEM or Engineering Master's degree programme.

The mission of the *master's programme* Industrial Engineering and Management is to train engineers who design solutions for IEM-related problems from a strong technological and research perspective. In the critical reflection 2016 IEM related problems are defined as: 'Problems in which (innovative) technology plays a central role but where the broader business context is of particular interest for the chosen solution as it influences the final technological design'. A prominent characteristic of the Groningen IEM master's programme is the strong focus on technology. The mission results in the following objectives: teaching students the knowledge and skills in the field of IEM to perform a thorough problem analysis, draft a satisfactory design/redesign of a technological process, and implement and validate complex technological products, processes and systems in a socio-technical business environment.

The panel noticed that the objectives of the bachelor's and the master's programme seem to be almost identical. In the opinion of the panel the difference in level between bachelor's and master's programme should be more articulated in the objectives. The difference in level is, however, more clearly visible in the intended learning outcomes, which are included in Appendix 3. The intended learning outcomes of the *bachelor's programme* describe that the graduates have the required knowledge to describe elementary technological products and processes, opposed to the intended learning of the *master's programme* that the graduates have the knowledge to describe complex and advanced technological processes and products in a managerial/ business context. Another indication of the difference in level between bachelor's and master's programme is that bachelor's graduates have the required knowledge, understanding and skills to conduct elementary academic research and master's graduates have the knowledge, understanding and skills for applying industrial engineering methodologies in research.

During the site visit, the programme management explained that the programmes have only been recently included in the IEM cluster together with the programmes of the Universities of Technology. The Groningen programme has a clear match with the other universities' programmes based on their shared emphasis on the context in which products are designed, involving various stakeholders. The Domain Specific Framework of Reference has been developed in close cooperation of all four universities involved. All programmes share the emphasis on the design context. The Groningen programmes distinguish themselves with a relatively strong focus on the mathematical-technological part of the domain and process and product technology. The programmes also meet the criteria of the Accreditation Board for Engineering and Technology (hereafter: ABET).

At the start of the programme, thirteen years ago, it was decided that 70% of its content must be dedicated to technology and 30% to management. This division is still valid and appreciated by staff and students. In its critical reflections, the programmes underline that the engineering design approach and the design context in an industrial setting are at the core of their curricula.

The programmes have close connections with industry, which is, among others, visible in the establishment of an Industrial Advisory Board. This board meets once a year and provides the programme management with advices about the profile and the curricula.

The assessment panel appreciates the programmes' descriptions of the ways in which the intended learning outcomes relate to their missions and objectives and the way in which they are positioned within Groningen University and within the IEM cluster in the Netherlands. The choices made are clear and rational. In discussion with students and alumni, it became clear to the panel that an objective about interdisciplinary cooperation could be formulated for the programmes, in addition to those described in the critical reflection. Students and alumni mentioned to consider the ability to cooperate with people from different disciplinary and educational backgrounds an important learning outcome. Alumni ascertained that IEM graduates easily take coordinating roles in inter- and multidisciplinary teams. They considered this particular competence very valuable and specific for the IEM programmes.

The intended learning outcomes sufficiently indicate what could be expected from programmes at bachelor's level and master's level, respectively. The panel also ascertained in the critical reflection that the intended learning outcomes meet the international accepted descriptions for academic bachelor's and master's programmes, the Dublin descriptors. The panel, however, noticed that the difference in level and orientation between the bachelor's programme and the master's programme could be articulated more clearly. The panel suggests to formulate the intended learning outcomes in such a way that they could be used in a more operational manner to further articulate the existing differences in level, profile and orientation between the bachelor's and master's programmes.

**Considerations**

The panel considers it positive that the Groningen IEM programmes have a distinctive strong focus on mathematical-technological subjects and translated this focus in the curricula. With this specific focus the programmes differentiate from the other IEM programmes in the Netherlands.

It is appreciated by the panel that the programmes have clearly described the way in which the mission and objectives of the programmes have been translated into the formulated intended learning outcomes.

The panel concluded that the intended learning outcomes meet the Dutch qualifications framework and tie in with the international perspective of the requirements set by the professional field and the discipline. They fit the Domain Specific Framework of Reference developed by the Dutch programmes for Industrial Engineering and Management and they meet the requirements of ABET.

The intended learning outcomes sufficiently indicate the differentiation between bachelor's and master's level at a global level. Nonetheless, the panel suggests to pay further attention to their formulation, and to elaborate on the differences in degree level between both programmes.

**Conclusion**
*Bachelor's programme Technische bedrijfskunde:* the panel assesses Standard 1 as 'satisfactory'.

*Master's programme Industrial Engineering and Management:* the panel assesses Standard 1 as 'satisfactory'.

**Standard 2: Teaching-learning environment**
The curriculum, staff and programme-specific services and facilities enable the incoming students to achieve the intended learning outcomes.

**Explanation**:
The contents and structure of the curriculum enable the students admitted to achieve the intended learning outcomes. The quality of the staff and of the programme-specific services and facilities is essential to that end. Curriculum, staff, services and facilities constitute a coherent teaching-learning environment for the students.

**Findings**

*Curriculum*
The *bachelor's curriculum* has an engineering design approach with a strong focus on technological and mathematical aspects. After a shared first-year, students make a choice for one of the two tracks: Production Technology and Logistics (PTL) or Product and Process Technology (PPT).

The first year of the bachelor's curriculum is focussing on the general engineering design skills and the technical and mathematical aspects of artefacts. The first year starts with an orientation course IEM; it furthermore contains four courses on mathematics, three courses on management, two on technology and two on methods and design (all courses 5 EC). In the second and third year, in addition to the track specific courses, students follow shared core IEM course units, dominantly in the field of management and business design, six courses (all 5 EC) in the second year and two courses in the third year. The students follow eleven (PPT) or twelve (PTL) track specific courses (65 or 70 EC in total, respectively). The final step in the bachelor's degree programme is the bachelor's thesis specified as the 'bachelor's integration project'. The students are supposed to integrate all – multidisciplinary – knowledge and competences learned during their bachelor's studies in this project. Bachelor students confirmed during the site visit that in their third year, they are well-prepared to make connections between previously taught topics and encountered subjects.

The same two tracks, PTL and PPT, are the basis for *the master's curriculum*. From the start of the master's programme, students make a choice for one of the two existing tracks: Production Technology and Logistics (PTL) or Product and Process Technology (PPT). The programme outline in the master's programme is similar for both tracks. The first year is mainly dedicated to compulsory courses (40 EC) and electives (20 EC). The second year consists of a design and a research project and of the course Research Methodology.

The content of the programmes is in line with the programmes management's view that the technological-mathematical part of the programme should be at least 70%. This focus is, although visible in the curriculum, not clearly reflected in the Dutch name of the bachelor's programme Technische bedrijfskunde, which suggests a more stronger focus on business administration. This could potentially mislead prospective students. The panel advises to clearly underline the technological-mathematical profile of its *bachelor's programme* during the enrolment process.

*Intake, dropout and study success*
The panel noticed that the programme has high entry levels, but also a relatively high dropout rate of first-year students at *bachelor's level*. This could be an indication of a high proportion of first-year students having made a wrong study choice. The high entry levels and relatively high dropout rate in the first year is possibly responsible for an undesirable and ineffective high work load for teachers, which could harm the quality of the programme. The programme management confirmed that expectation management for incoming students is an issue that requires attention. The panel recommends to evaluate the effectivity of the current matching interviews with interested vwo-graduates and to learn from other successful matching systems e.g. from Utrecht University.

A substantial number of bachelor's and master's students exceed the standard study time. Although the presented figures show that study success of the bachelor's students is improving, the average study duration in the bachelor's and the master's programmes should remain a point of concern for the programme management in the opinion of the panel. The five-year success rate of the *bachelor's students* who continued their studies in the second year increased from 80% (cohort 2009) to 86% (cohort 2010) and the three-year success rate increased from 22% (cohort 2009) to 31% (2012). The study success of the *master's programme* declined in the period 2010-2013; the 3-year success rate for the cohort 2009 was 81% and for the cohort 2012 69%. The critical reflection provides several reasons for this decline, the most important probably being the implementation of bachelor-before-master rule in 2012, which prohibits students to start with their master's courses before having obtained their bachelor's degree.

*Coherence*
The panel also has noticed that the bachelor students have to make a choice for one of the two tracks relatively early in their studies. Before its visit, the panel wondered whether this choice for a track is too early. In discussion with the panel, the interviewed students refuted these fears: they indicated to feel ready for making a well-informed choice for one of the two tracks in their second year. They felt sufficiently informed about the content of both tracks and the consequences of their choice for their further careers.

Coherence in both programmes is enhanced by the fine tuning and calibrating between the involved teachers. Yearly, an away day is organised for all teaching staff to reflect on the current curriculum and to brainstorm about new developments. Furthermore, in the critical reflection of the *bachelor's programme* is described that several learning trajectories enhance the coherence in the curriculum. The course 'Orientation to IEM' is in particular developed to create awareness of all key IEM academic and engineering skills and is the first course in a trajectory in Basic engineering design skills and concepts. This trajectory comprises next to 'Orientation to IEM', 'IEM Methods and Design', 'IEM integrated Design Project' and 'Business System Design', culminating in the bachelor's thesis. The development of the learning trajectories is an improvement following the recommendations by the previous assessment panel. This is in the view of the panel a positive development, the trajectories are clear and in their opinion truly supporting coherence. The students, however, did not recognise the trajectories at first. The panel advises to present these trajectories more explicit.

The intended learning outcomes have been adequately translated in learning outcomes for the courses in the programme. The *bachelor curriculum* is carefully designed to enable the students to acquire knowledge, understanding and skills to describe and design elementary technological processes and products in a managerial/business context. In the *master's programme,* the students are enabled to acquire more specialised knowledge and understanding of IEM and to develop the research and design skills required for the master's level.

The panel, however, noticed that the *bachelor's programme* in particular is a rigid programme, since it provides very limited room (5 EC for the PTL track and 10 EC for the PPT track) for individual choices by the students. Even the elective courses should be chosen out of a limited list. Students confirmed that a study period abroad has to be done in their own time, in fact extracurricular. The panel concluded that students are not really stimulated to study abroad within the degree programme, which seems to be contradictory to the ambition of the programme to become an international bachelor's programme.

The programme management set the target for internationalisation to 30% inflow of foreign students. This target is not yet obtained. The management has no targets for their own students studying abroad for a part of their studies. The assessment panel is of the opinion that, in line with the internationalisation ambitions, students should be encouraged to do part of their regular studies abroad. The panel encourages the programme management to proceed in the line that was sketched during the site visit to develop another, more integrated, way of teaching the basic competences to the students in order to create more space for individual choices in the curriculum, which would benefit the internationalisation ambitions.

*Teaching and teaching methods*

It was clear to the panel that the teachers bring their present research into the programmes and that there is a positive exchange between research and teaching. In that way, classical subjects are brought into the programmes with a new view and angle.

Distinctive are also the design (25 EC) and the research (30 EC) projects in the *master's programme*. The panel learned that the setup of the master projects has only recently been changed. The former optional business project has been replaced by a compulsory design project. Both research and design projects, their learning outcomes and assessment criteria have been more clearly defined. In the research projects, the staff members involve the students in their research and aim at publishing together, while the design project enables the students to connect with industry and prepare themselves for a position on the labour market. The panel is positive about active involvement of master's students in the department's research projects. The panel applauds the decision of the programme management to redevelop the setup of the master's projects. With these two projects the master's students can develop scientific research skills, and are able to acquire experience in designing in actual practice.

The teaching methods, lectures and tutorials and a few laboratory courses are in line with the contents of the curricula and support the students to achieve the learning outcomes. The panel, however, found the teaching methods relatively old-fashioned and suggests to invest more in exploring the possibilities of blended learning, for example a combination of e-learning and teacher-student interaction. The panel thinks that a blended learning concept could be a valuable addition to the recently introduced learning communities. These learning communities are very positively evaluated by the panel. During the site visit was explained by the programme management that the first-year cohort is organised into teams of 10-15 students, who are tutored by a team of teaching-assistants. Learning community coaches guide first-year students on their first steps towards acquiring academic and engineering skills. In their learning communities students work on projects and group assignments. The learning communities play a crucial role in integrating knowledge and skills acquired in the distinctive courses. The panel has seen that the programme management is putting a lot of effort in facilitating these learning communities and is determined to make them a success. Students are positive about the learning communities and confirm that the communities help them to achieve the intended learning outcomes.

The panel learned during the site visit that the programme committee plays an important role in the governance of the programmes. The programme committee proactively advises the programme management on issues concerning coherence and feasibility of the programme. The programme committee uses the results of student evaluations to identify points for improvement.

The degree programmes have a multidisciplinary character, which is reflected in the teaching staff. Teachers come from different faculties (Faculty of Science and Engineering and the Faculty of Economics and Business) and different disciplines (amongst others Chemical Technology, Pharmaceutical Technology, Bio-pharmacy, Bio-technology, Computational Physics, Operations, Business Administration, Law and Economics). A substantial amount of teaching tasks is performed by teaching assistants (recruited among the PhD and master's students). The academic staff, however, is always responsible for and guarantees the quality of the teaching and examination. The teachers themselves told the panel, furthermore, that they frequently invite guest lecturers from the industry in their courses.

The quality of the teaching is monitored by the programme committee. The students in general spoke very positive about the quality of the teaching. The academic teachers are required to hold a University Teaching Qualification (UTQ). In December 2015 78% of the staff holds a UTQ. Recently appointed staff is enrolled in the courses to obtain the qualification.

The Bachelor's student-teacher ratio is rather high 35:1 (Master's 18:1), which can partly be explained by the high student inflow in the first year. The programme management mentioned that new academic staff members are currently hired, which is appreciated by the panel.

**Considerations**
The assessment panel established that content and structure of the *bachelor's programme* Technische bedrijfskunde and the *master's programme* Industrial Management and Engineering enable the students to achieve the intended learning outcomes.

In its considerations the panel assessed the content, the coherence, the teaching methods and the feasibility of the programme, as well as the quantity and quality of the teaching staff. The quality of the teaching staff is good and the efforts within the teaching staff to cooperate and fine-tune the course units are much appreciated by the panel. In particular, the panel is positive about active involvement of master's students in the department's research projects. The panel endorses the decision of the programme management to redevelop the setup of the master's projects.

The panel assessed both programmes positively. The panel appreciates the introduction of learning trajectories, which have, together with the intensified cooperation between the teachers, enhanced the coherence. The panel is also very positive about the introduction of the learning communities, which support the students to develop academic and engineering skills and to integrate the content of the distinctive courses. The teaching methods, however, could be more innovative; the panel recommends exploring the possibilities of blended learning.

There remain a few points of concern which have been brought forward to and have been recognised by the programme management. These concerns are the high inflow of students and the high dropout during the first year and the lack of freedom of choice in the curriculum, which does not work in favour of the internationalisation ambitions. The panel recommends to evaluate the current matching system with the interested vwo-graduates and to consider alternative or additional measures to manage their expectations. The panel furthermore advises to allow for further choice and real electives within the curriculum and to encourage and enable students to take part of their studies at universities abroad.

**Conclusion**
*Bachelor's programme Technische bedrijfskunde:* the panel assesses Standard 2 as 'satisfactory'.

*Master's programme Industrial Engineering and Management:* the panel assesses Standard 2 as 'satisfactory'.

**Standard 3: Assessment**
The programme has an adequate assessment system in place.

**Explanation**:
The tests and assessments are valid, reliable and transparent to the students. The programme's examining board safeguards the quality of the interim and final tests administered.

**Findings**
The Faculty of Science and Engineering has described its assessment policy in the Quality Assurance Manual, an extensive manual intended to describe the complete quality assurance cycle. The Quality Assurance Manual contains practical standards (protocols) for the implementation of all aspects of quality assurance at FMNS, including questionnaires for student evaluations and checklists. The Board of Examiners (hereafter: BoE) is responsible for the examination and assessment quality of the degree programmes. The BoE consists of three (internal academic staff) members and an external member, who is also an expert in testing.

The assessment panel studied a selection of test files 'course unit assessment overviews', a selection of bachelor's integration projects and the accompanying assessment forms, a selection of master's design projects and master's research projects and the assessment of these projects. Furthermore the panel had a meeting with the Board of Examiners during the site visit.

The panel was impressed by the active involvement of the Board of Examiners in securing the quality of education, testing and examination. The BoE's main concern is quality assurance, next to its task to address individual student requests. The BoE uses the rules and regulations available to perform its tasks and follows the guidelines, but in the end the independent position of the BoE is leading. The quality assurance tasks of the BoE comprises:

- monitoring the quality of all assessments carried out in individual course units of the programmes both at procedure and content level;
- assessing whether the study programmes of individual students sufficiently comply with the final level and qualifications of the programme;
- advising the programme management on the quality of the Assessment Plan in terms of knowledge and skills and whether the modes of assessment sufficiently cover the programme learning outcomes.

The panel observed that the BoE is performing all these tasks on an intensive level.

As is described in the critical reflections and also verified during the site visit by the assessment panel, the programme management regulated procedures to assure the quality of testing and examination. The programme management annually drafts an assessment plan, which is checked by the BoE. For each course unit an assessment overview, a systematic description of the links between learning outcomes, modes of instruction and modes of assessment and marking, the students' background and the position of the course in the curriculum, is drafted. Individual projects, like the bachelor's integration project and the master's design project and master's research project are assessed using a standard assessment form and two supervisors involved. The BoE performs random checks of the theses and their assessments and provides feedback to the supervisors.

Exams and assignments are always drafted and checked by two lecturers to ensure that the exam questions are clear, unambiguous and sufficiently assess whether the various learning outcomes of the course have been attained. The students report back that the testing and assessments procedures are transparent. They know in advance how they will be tested and what the criteria are.

In reaction to the recommendations of the previous programme assessment the assessment forms have been adjusted to create more space for justification of the marks. The BoE mentioned during the site visit that it advised the programme management to introduce rubrics in the forms to standardise the marking. The introduction of the rubrics will be first implemented in the first-year courses.

The BoE has regular meetings with the deputy directors and is also present at the teachers meeting to inform the teachers about the policies and regulations.
The panel was impressed by the active, professional way the BoE is performing its tasks and compliments the BoE for its thorough work. The panel also established that the quality assurance system in the FMNS is fully developed and implemented, it is well thought through and brought into practice.

**Considerations**
The assessment panel established that the *bachelor's programme* Technische bedrijfskunde and the *master's programme* Industrial Engineering have a very good, extensive and fully implemented assessment system. The panel appreciates the introduction of a yearly Assessment Plan and the Course Unit Assessment Overviews. The BoE has demonstrated that it has a complete insight in all relevant material and that it can guarantee the quality of the testing and examination. The assessments and tests are regularly checked by the BoE for validity and reliability. The panel was impressed by the way the BoE performs its tasks.

**Conclusion**
*Bachelor's programme Technische bedrijfskunde:* the panel assesses Standard 3 as 'good'.

*Master's programme Industrial Engineering and Management:* the panel assesses Standard 3 as 'good'.

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

**Explanation**:
The level achieved is demonstrated by interim and final tests, final projects and the performance of graduates in actual practice or in post-graduate programmes.

**Findings**
In the critical reflection of the *bachelor's programme* is described that the achieved learning outcomes are best described by the complete list of marks earned by a student, because no single element of the programme will give a complete view. The bachelor's integration project, however, provides, according to the critical reflection, a good indication as a proof of competence.

The panel studied a selection of fifteen bachelor's integration projects to assess whether the graduates had achieved the intended learning outcomes. It studied in total nineteen final works for the master's programme: fifteen master theses (from 2013-2015) and two recent design projects and two recent research projects, finished in 2016 to also assess the recent changes to the master's final work. An overview of both selections is included in appendix 6. The panel would have marked some projects slightly lower or higher (0,5-1 points), but in their opinion all students' pass mark is considered justified. Some of the (older) bachelor projects were not yet assessed with the new assessment forms, which made it more difficult to understand the reasons for the final marking as the forms did not contain a justification for the marking. The new assessment forms turn out to be a big improvement in that respect.

The *master's graduation trajectory* consists of two projects: a research project and a design project, which are quite different in nature, but cover the learning outcomes for an IEM engineer. The aim of the research project is to investigate problems related to IEM design tasks, using scientific methodologies. The focus of these projects is on research skills and the projects are carried out in an academic research group. The main objective of the design project is to design a product, process or system in an industrial environment. These projects are usually carried out in, or in cooperation with, companies. The business context is dominant. The panel finds the redevelopment of the master's project, i.e. a research and a design project, a good decision, since in that way the students get the chance to demonstrate that they are able to perform multidisciplinary projects in a complex environment as well as performing an academic research project.

The panel assessed the *master theses* in particular as technically solid and based on an adequately trained analysis scheme. The theses were less focused on innovative solutions for business processes and organisation, but they were certainly an adequate demonstration of the students' achievement of the intended learning outcomes. Some *bachelor projects* contained few literature references. The panel is of the opinion that this aspect can be improved. Over all, the bachelor projects were at adequate degree level. The panel concluded that both the bachelor graduates and the master graduates demonstrated that they sufficiently achieved the intended learning outcomes of the bachelor's and the master's programme, respectively.

The alumni of the *bachelor's programme* felt well prepared for the master's programme. This reflection was also valid for a bachelor student who chose to do another master programme after her bachelor IEM. The panel also spoke to alumni of *the master's programme*, who reported that they easily found a job and felt sufficiently prepared for the labour market. Some of the master's alumni suggested that, considering their experiences in the work field, they could have used some more mathematics and use of statistical software in the programme. The number of graduates that pursue an academic career is limited. Most students are interested in a job in industry, whereas a PhD trajectory is associated with lab work. The alumni of the master's programme especially appreciated the competences they developed in working with colleagues from different backgrounds. The IEM graduates describe themselves as all round experts, rather than classical technical experts, who are able to take a helicopter view.

There is at present no formal alumni network and contacts between alumni and the programme are incidental, but feedback is much appreciated by the programme. The panel recommends the programme management to facilitate the establishment of an alumni network and to make more and more structural use of their feedback.

**Considerations**
The panel concludes that the graduates of the bachelor's and the master's degree programme have achieved the intended learning outcomes. The level of the graduation projects concurs with the level that is expected from an academic bachelor and master programme, respectively.

**Conclusion**
*Bachelor's programme Technische bedrijfskunde:* the panel assesses Standard 4 as 'satisfactory'.

*Master's programme Industrial Engineering and Management:* the panel assesses Standard 4 as 'satisfactory'.

# GENERAL CONCLUSION

The University of Groningen offers a bachelor's programme Technische bedrijfskunde and a master's programme Industrial Engineering and Management with a strong focus on the technological and mathematical aspects. The degree programmes deal with problems in which (innovative) technology play a central role, but where the broader business context is also of particular interest for the chosen solution.

The panel assessed standard 1 of both the bachelor's and the master's programme as satisfactory. The intended learning outcomes have been concretised with regard to content, level and orientation; they meet international requirements. Standard 2 is also assessed as satisfactory for the bachelor's and the master's programme. The panel established that the curricula, staff and programme-specific services and facilities enable the incoming students to achieve the intended learning outcomes. The panel assessed standard 3 for both programmes as good. The panel was impressed by the thoroughness of the assessment system that is implemented in the Faculty, and by the professional way the Board of Examiners of the Industrial Engineering and Management programme performs its tasks. Standard 4 is assessed as satisfactory. The panel concluded that the bachelor's and the master's graduates had achieved the intended learning outcomes.

Considering the assessments of the four criteria for the bachelor's programme Technische bedrijfskunde and the Master's programme Industrial Engineering and Management, the panel assesses these programmes as satisfactory.

**Conclusion**
The panel assesses the *bachelor's programme Technische bedrijfskunde* as 'satisfactory'.

The panel assesses the *master's programme Industrial Engineering and Management* as 'satisfactory'.

# APPENDICES

# APPENDIX 1: CURRICULA VITAE OF THE MEMBERS OF THE ASSESSMENT PANEL

**Panel chair**

Professor Rob Van der Heijden graduated in 1981 from Eindhoven University of Technology as a building engineer. He received his PhD in Building Engineering from the same university in 1986. From 1987-1993 he worked as associate professor at the Faculty of Building Engineering of TU Delft. In 1994, he was appointed full professor in Transport and Logistics at TU Delft, followed in 2001 by an appointed as full professor in Urban and Regional Planning at the Radboud University Nijmegen. Between 2008-2010, he was Director of Research at the Institute of Management and Vice-Dean of Research at the Nijmegen School of Management (NSM). Professor Van der Heijden was Dean of the Nijmegen School of Management from 2011-2016. Since Spring 2016, he is professor in Innovate Planning Methods within the NSM. His research is in the fields of spatial planning, decision making and governance with a special focus on issues of transport, logistics and infrastructure development. He has been member of various advisory committees.

**Panel members**

Professor Harrie Eijkelhof has specialised knowledge of didactics and teaching methods in science education. Until his retirement in 2014, he was Director of the Freudenthal Institute for Science and Mathematics Education at the Faculty of Science at Utrecht University (2011-2014). Previously, he was Professor of Physics Education at the Faculty of Physics and Astronomy at the same institution (1997-2011). Professor Eijkelhof has ample experience in teaching, educational models, didactics, assessment and professional development of executives in university education. From 2005 to 2010, he was Vice-Dean of undergraduate studies at the Faculty of Science, Chairman of the Board of Studies of the Undergraduate School, member of the examination board of Liberal Arts and Sciences and a member of the Advisory Board of Education at Utrecht University.

Professor Emmo Meijer studied Chemistry in Amsterdam (Vrije Universiteit), and obtained his PhD in 1979. He worked for DSM for several years in research and business management and was involved in the transformation of DSM to a more life sciences oriented industry. In 2005 he became senior vice-president of Unilever and was Corporate Director R&D of FrieslandCampina from 2011-2014. Next to these industrial affiliations he was part time professor of Eindhoven, University of Technology. President of the Netherlands Academy of Technology and Innovation, director of the Royal Holland Society of Sciences and Humanities, president of the Energy Advisory Committee, president of the Top Institute Food and Nutrition and member of several other national and international organisations in science and innovation.

Dr Margriet Nip graduated in Geology at the University of Leiden in 1983. She received a PhD degree from Delft University of Technology in 1987. After holding a research position at FOM Institute AMOLF in Amsterdam, she moved to Spain. Here, she worked in industry until her move back to the Netherlands in 1994. After three years in the Dutch dairy industry, she joined Koninklijke Hoogovens in 1997. After some years, she left Koninklijke Hoogovens to found the Dutch Centre of Expertise of Sustainable Water Technology, Wetsus. She quickly returned to Koninklijke Hoogovens/Corus/Tata Steel; first as General Manager Services at Aluminium Delfzijl, then as Director of Product Market Development and Technology and Member of the Board of Directors of Tata Steel Strip Products IJmuiden. In this period, Dr Nip was Chairman of the Supervisory Board of the Materials Innovation Institute (M2I), and Member of the Commauté de Sidéurgie of the Centre de Recherche (CRM). Since 2012, she is responsible for the Raw Materials Procurement for Tata Steel Group.

Dr Hector Ramirez Estay is Associate Professor at the Department of Automatic Control of the Université de Franche-Comté and Researcher at the Department of Automatic Control and Micro-Mechatronic Systems at Franche-Comté Electronique Mécanique Thermique et Optique - Sciences et Technologies in Besançon, France. Dr Ramirez Estay was trained in Electrical Engineering Sciences at the University of Concepción in Chile and received doctorate degrees in Electrical Engineering Sciences from the University of Concepción (2012) and in Control Theory from the Université Claude Bernard Lyon 1 (2012). His current research focuses on modelling and nonlinear control of systems described by ordinary and partial differential equations with application to micro/nano-electromechanical and thermodynamical systems.

Sofie Vreriks BSc (student member) is in her second year of her master Industrial Engineering and Management at the University of Twente. From 2010 – 2011, she studied Communication Science before moving to Industrial Engineering and Management, also at Twente. Vreriks received her bachelor's degree in 2014, with a minor in International Business and Exploration. After finishing her undergraduate degree, she worked for a year as an intern and a project coordinator for Royal Philips in Amsterdam.

# APPENDIX 2: DOMAIN-SPECIFIC FRAMEWORK OF REFERENCE

Domain-Specific Frame of Reference Industrial Engineering and Systems Engineering
*(As confirmed in Utrecht on 10 March 2016)*

This document has been written as a short summary of views on the field of Industrial Engineering and Systems Engineering (IE&SE). These views have been gathered from organizations that focus on the professional development and application of the field http://esd.mit.edu/;http://www.abet.org/). In addition, SE engineers (http://www.iienet.org; http://msom.society.informs.org; http://www.informs.org; http://www.incose.org) and leading academic programs in the field (http://ieor.berkeley.edu/; http://www.isye.gatech.edu/; http://www.cesun.org; http://www.stanford.edu/dept/MSandE/; http://www.epp.cmu.edu/; http://esd.mit.edu/; http://www.seor.gmu.edu/). A few excerpts from these texts are included in the separate text box.

Although there are some clearly common elements in these descriptions, we observe that the various different emphases of these organizations' IE&SE programs have necessitated each of them to formulate their own view of what the field of Industrial Engineering and Systems Engineering represents in education, application, and research. The same also holds for the IE&SE programs at UG, TUD, TUe, and UT. This document gathers the overarching elements of these programs, but we emphasize that each of these IE&SE programs has unique elements that will be highlighted in the self-assessments.

**1. Common elements of the field of IE&SE**
These common elements concern: (a) the common basis, (b) the focus: (re-)design, implementation, installation, and improvement of products, processes and systems, (c) broadly applied in private and public domains and within and between organisations, (d) the application of quantitative methods (and combination with qualitative methods), and (e) complex problem solving with a scientific and a pragmatic multidisciplinary approach.

**(a) The common basis**
Industrial Engineering (IE) and Systems Engineering (SE) are interrelated.[1] IE is concerned with the design, improvement, implementation and installation of integrated systems of people, information, materials, equipment and energy. It focuses on the analysis, design and control of (innovative) processes, products and systems in an industrial and/or societal environment, both at the level of individual organisations and supply networks as well as strategic issues. It involves the use of new processes, materials and production- and manufacturing techniques in innovative ways. SE mainly focuses on inter-organisational questions that involve the use of technology and the interests of multiple stakeholders, typically linking public and private organisations. As a consequence the common basis of IE en SE draws upon specialised knowledge and skills in the mathematical, physical, chemical and social sciences together with the principles and methods of engineering analysis and design in order to specify, predict, and evaluate the results to be obtained from the systems involved.

**(b) The focus: analysis, design, implementation, and performance improvement of processes, critical infrastructures, and systems**
IE&SE is concerned with the design and improvement of operational and/or strategic processes and integrated systems. These processes or systems provide products or services to customers or to the society at large. As such both private and public organisations are concerned. The design and improvement of products, processes and systems considers multiple goals and the availability of limited resources, such as time, money, materials, energy and other resources. Several organizations and multiple stakeholders may be involved (supply chains, alliances, public-private partnerships) and governance structures can be part of design and improvement initiatives. The scope of design thus may include supply chain networks, production and manufacturing techniques, products, control of

[1] "Industrial Engineering" refers to the programmes at TU/e and UT, while the term "Systems Engineering" better fits most programmes at TUD.

systems, implementation, installation and validation. The multidisciplinary, integrated design approach including the design context distinguishes IE and SE's from specialized engineering disciplines. In summary, IE's and SE's may be considered Productivity and Efficiency Professionals.

**(c) Broadly applied, both in private and public domains and both within and between organizations**
IE&SE is used in a variety of fields. It applies along all steps in the product life cycle, from research and development over design, manufacturing, distribution and disposal. And it applies in all phases of the value chain. Whereas initial applications were mainly limited to industrial settings, we now witness more and more applications in the service industry. Its principles apply as well in all fields of the private as in the public sector. Today there is a fast growth of applications in banking, healthcare, transportation, and the like.

Therefore the term "industrial" can be misleading; this does not mean just manufacturing. It encompasses service industries as well. It has long been known that industrial engineers have the technical training to make improvements in a manufacturing setting. However, many of the same techniques can be used to evaluate and improve productivity and quality in a wide variety of service industries, as well as in the public sector. The term "Systems Engineering" emphasizes this broader scope for design, improvement, and problem solving.

**(d) The application of quantitative and qualitative methods**
IE&SE is a field of engineering and one important element of its approach to the design and improvement of products, processes and systems is the use of data analytics and quantitative modelling methods. These are derived from fields such as operations research, management science, mathematics, natural sciences, economics, data analysis and statistics, information systems, game theory (gaming, simulation and Q-methods), engineering and social science methods such as interviews and questionnaires.

**(e) Complex problem solving with a scientific and pragmatic multidisciplinary approach**
Complex problems where value systems may clash and the status of knowledge claims may be disputed are central to IE&SE. In order to be able to solve these kinds of problems, it is necessary to synthesize knowledge from different disciplines (e.g., engineering, natural sciences, (institutional) economics, mathematics, organizational behaviour, law, psychology, although not all disciplines are equally important in all problem domains). IE&SE draws upon specialized knowledge and (analytical) skills in the mathematical, physical, and social sciences, together with the principles and methods of engineering analysis and design. Unlike traditional disciplines in engineering, IE&SE addresses the role of human decision-makers and other stakeholders as key contributors to the inherent complexity of systems. The programmes offer the relevant knowledge and skills from different disciplines and provide a framework for the application and integration of this knowledge in analysing a problem situation and in designing and implementing solutions. In brief, IE's and SE's might support (scientific) decision making.

Besides scientific IE&SE people also ought to be pragmatic people. They work to understand and resolve real problems from society and hence - as stated above - need to combine the knowledge and experience from many disciplines to develop project and process-management expertise and communication skills. They choose their method so as to fit the problem, which means that they combine the quantitative and problem-solving approach of engineers with research methods and qualitative insights from the social sciences.

**2. Generic competences**
Taking into account the before mentioned common elements of the field generic competencies for industrial and systems engineering are listed below:

- Sufficient understanding of science, technology and technological innovation;
- Keen analytic mind-set combined with a drive to synthesize towards a solution;

- Competent in translating complex issues in workable models and design and execute appropriate research programmes;
- Adequate mathematics skills for modelling and executing research activities;
- Able to conduct standard experiments, tests and measurements, and to analyse and interpret and apply the results in order to improve products, processes and systems;
- Able to (re)design products, processes and systems in an IE&SE context;
- Adequate understanding and competences in a number of technical, economic and social disciplines to underpin research programmes;
- An adequate understanding of the drivers of socio-,economic and political organizations in society;
- Able to assess the impact of IE&SE products, processes and systems in a business, societal and global context;
- Able to organize and drive for efficiency and effectiveness;
- Resourcefulness and creative problem solving;
- Excellent communication, listening, and negotiation skills;
- Ability to adapt to many environments, interact with a diverse group of individuals and understand the roles of various stakeholders in the processes;
- Experience in working in an interdisciplinary and international environment;
- Able to identify the arising ethical dilemma and to reflect on this dilemmas.

**3. BSc and MSc levels**

The specific blend of competencies varies per programme and is laid down more specifically in the final qualifications of each programme. Although the emphasis varies among the programmes, there is a differentiation between the BSc and MSc levels regarding to

- Complexity of the problem situations (in terms of technical and/or stakeholder complexity and/or the number of disciplines involved);
- The amount of information necessary, known, and available from the practical problem situation;
- The level of autonomy.

Bachelors receive a sound general education in basic fields of IE&SE, like Natural Sciences, technology, engineering, optimisation, production- and process techniques, engineering economy, business economy, organisational theory, social sciences, etc..) However, specific choices in these basic fields, varies per programme. They should be able to continue studies on a more in depth and specialised Master's track or they may fill appropriate positions in business.

Master programs in IE&SE generally offer different fields of study in which students can specialise. Examples of such fields are operations management, operations research and management science, CIT, product design and logistics, policy analysis, man-machine systems, performance analysis, supply chain management, process- or production techniques, innovation processes, control engineering, etc.

Whereas bachelors are mainly involved in analysis (as the initial step in the design cycle), Masters typically deal with design questions. Above that they should also be exposed to research questions. Masters should be able to formulate and carry out independent research projects.

The IE&SE Bachelor programs provide an excellent basis for one of the IE & SE Master programs, but students in IE&SE Master programs also can have various undergraduate backgrounds in engineering and other quantitative fields. Graduates of a Master's programme will typically start their career as engineers, project or planning managers, functional managers, policy analysts/advisers, engineering consultants and the like. But they may as well start an academic track through further involvement in research (e.g. PhD and academic positions). They should be able to move later on to managerial positions (e.g. as CTO). Some may prefer to become private entrepreneurs.

Excerpts from: http://www.iienet.org/Details.aspx?id=282

Excerpts from: http://www.iienet.org/Details.aspx?id=282

**Institute of Industrial Engineers** (IIE) **Definition of Industrial Engineering:**

'IE is concerned with the design, improvement and installation of integrated systems of people, materials, information, equipment and energy. It draws upon specialised knowledge and skill in mathematical, physical and social sciences together with the principles and methods of engineering analysis and design, to specify, predict and evaluate the results to be obtained from such systems'

Excerpts from http://www.stanford.edu/dept/MSandE/about/MSandE-5yr.pdf

**Stanford** Engineering established the Department of Management Science and Engineering five years ago with a logic and a purpose: engineers know how to analyze and solve problems and they thoroughly understand technology. With this quantitative background and additional training, for example in social sciences or finance, engineers should therefore be leaders in management and public policy.

The department's eight research areas [are]: organizations, technology management and entrepreneurship; production and operations management; decision analysis and risk analysis; economics and finance; optimization and the analytical tools of systems analysis; probability and stochastic systems; information science and technology; and strategy and policy. MS&E also includes several centres and programs such as the Energy Modelling Forum and the Centre for Work, Technology and Organization. In addition, it hosts the Stanford Technology Ventures Program. The department's strengths are also manifest in the talents of students and alums who work in investment banking, management consulting, and other fields that have not been closely associated with engineering in the past. These fields will be in the future because a deep understanding of technology has become critical to their operations. "For example, a growing number of people address finance problems using methods that have been traditionally associated with engineering systems analysis," says Paté-Cornell, referring to the fast-growing specialty of financial engineering. Paté-Cornell's hope is that more engineers will also join the ranks of government and use their skills to shape and implement policies.

MS&E students gain the training that they need to be leaders in finance, industry, policy, or other specialties by completing a core engineering curriculum, followed by a concentration in an area such as finance, operations research, production, or public policy.

Excerpts from www.isye.gatech.edu

**Georgia Tech:** Industrial engineering (IE), operations research (OR), and systems engineering (SE) are fields of study intended for individuals who are interested in analyzing and formulating abstract models of complex systems with the intention of improving system performance. Unlike traditional disciplines in engineering and the mathematical sciences, the fields address the role of the human decision-maker as key contributor to the inherent complexity of systems and primary benefactor of the analyses. In short, as practitioners and researchers in IE/OR/SE, we consider ourselves to be technical problem solvers. We are typically motivated by problems arising in virtually any setting where outcomes are influenced by often complicated and uncertain interactions, involving a variety of attributes that affect system performance. Against this backdrop, students have historically been attracted to our academic programmes with a variety of career objectives and from a host of disciplines and academic interests.

# APPENDIX 3: INTENDED LEARNING OUTCOMES

*Bachelor's programme Technische bedrijfskunde*

Holders of a Bachelor's degree in Industrial Engineering and Management have:

1. The required knowledge to describe elementary technological products and processes within a business context.
2. The required understanding to determine and assess the functionality and performance of these products and processes in a multidisciplinary way (e.g. from technological and business perspectives as well as those of a variety of stakeholders).
3. The required skills to design, redesign, implement and subsequently validate these products and processes.
4. The required knowledge, understanding and skills for 'Life-Long Learning' (including finding information and using IT applications) to function largely autonomously.
5. The required knowledge and understanding of technology, business studies, mathematics and natural sciences to successfully complete a follow-on Master's degree programme in Industrial Engineering.
6. An academic attitude, i.e. the required knowledge, understanding and skills to conduct elementary academic research.
7. The required skills to communicate effectively about ideas and solutions with both engineers and managers.
8. Basic knowledge in the field of leadership, socially and ethically responsible behaviour in order to apply technology.

*Master's programme Industrial Engineering and Management*

After the Master's degree programme Industrial Engineering and Management, students have:

1. The knowledge to describe complex and advanced technological processes and products in a managerial/business context.
2. The understanding to diagnose the functionality and performance of such processes and products in a multi-disciplinary way (e.g. technological and managerial and form viewpoint of various stake-holders).
3. The skills to (re)design, implement and then evaluate such processes and products.
4. The knowledge, understanding and skills for doing research, i.e. applying industrial engineering methodologies in research.
5. The knowledge, understanding and skills for life-long learning (including information retrieval and ICT-use) needed to function autonomously.
6. The skills to think critically and communicate scientifically about ideas and solutions with engineers and managers.
7. The knowledge and understanding of advanced technology, managerial/business sciences and mathematics to do research and to enter a PhD-programme in Industrial Engineering or a related discipline.
8. Professional skills for managerial, societal and ethical behaviour when applying technology.

# APPENDIX 4: OVERVIEW OF THE CURRICULUM

*Bachelor's programme Technische Bedrijfskunde*

An overview of the curriculum of the IEM Bachelor's degree programme (2014-2015):

| Course Units | ECTS |
|---|---|
| ***Propaedeutic Phase*** | |
| Orientation to IEM | 5 |
| Global Supply Chain Management | 5 |
| Calculus for IEM | 5 |
| Linear Algebra & Multivariable Calculus for IEM | 5 |
| Financial Accounting | 5 |
| Fundamentals of Process and Product Technology | 5 |
| Physical Systems for IEM | 5 |
| Algorithmics | 5 |
| IEM Methods and Design | 5 |
| IEM Integrated Design Project | 5 |
| Statistics and Stochastics | 5 |
| Management Accounting | 5 |
| | |
| ***Post-Propaedeutic Phase: second year*** | |
| Joint programme | |
| International Business Law for IEM / Nederlands Bedrijfsrecht | 5 |
| Operations Research 1 | 5 |
| Outlining & Implementing Innovation Strategy | 5 |
| Marketing | 5 |
| Physical Transport Phenomena 1 | 5 |
| Production Planning and Quality Control | 5 |
| PTL track | |
| Mechanics | 5 |
| Materials Science and Engineering | 5 |
| Production Techniques | 5 |
| Modelling and Analysis of Complex Networks | 5 |
| Applied Manufacturing Research | 5 |
| Signals and Systems | 5 |
| PPT track | |
| Structures and Molecules | 5 |
| Technical Thermodynamics | 5 |
| Polymer Chemistry | 5 |
| Single-Phase Reactors | 5 |
| Separation Processes | 5 |
| Biological Systems | 5 |
| | |
| ***Post-Propaedeutic Phase: third year*** | |
| Joint programme | |
| Business System Design | 5 |
| Work Organization and Job Design | 5 |
| PTL track | |
| Control Engineering | 5 |
| Numerical Methods | 5 |
| Mechatronics | 5 |
| Computer Aided Design & Manufacturing | 5 |

| | |
|---|---|
| Digital and Hybrid Control Systems | 5 |
| Design and Construction | 5 |
| Elective | 5 |
| Integration Project | 15 |
| PPT track | |
| General Process Equipment | 5 |
| Practical course (bio-) process technology | 5 |
| Special Process Equipment | 5 |
| Multiphase Reactors | 5 |
| Product Technology | 5 |
| Electives | 10 |
| Integration Project | 15 |

*Master's programme Industrial Engineering and Management*

| Course unit name | Year of programme | ECTS |
|---|---|---|
| ***Core modules*** | | |
| Technology-based Entrepreneurship | 1 | 5 |
| Sustainability for Engineers | 1 | 5 |
| Systems Engineering | 1 | 5 |
| Research Methodology | 2 | 5 |
| Master's Design Project IEM | 2 | 25 |
| Master's Research Project IEM | 2 | 30 |
| ***PPT Track course units*** | | |
| Bio-based Products | 1 | 5 |
| Interfacial Engineering | 1 | 5 |
| Polymer Products | 1 | 5 |
| Advanced Product Engineering | 1 | 5 |
| Physical Transport Phenomena 2 | 1 | 5 |
| Electives | 1 | 20 |
| ***PTL Track course units*** | | |
| Foundations of Logistics Systems Engineering | 1 | 5 |
| Robotics | 1 | 5 |
| Simulation of Logistic Systems | 1 | 5 |
| Analysis and Control of Smart Systems | 1 | 5 |
| Surface Engineering & Coating Technology | 1 | 5 |
| Electives | 1 | 20 |

# APPENDIX 5: PROGRAMME OF THE SITE VISIT

| **Monday November 14 2016** | | |
|---|---|---|
| 08.15 | 8.30 | Arrival panel at university<br>Welcome by<br>dr.ir. G.H. Jonker Deputy programme director bachelor and<br>drs. K. de Jonge, Programme coordinator |
| 08.30 | 11.30 | Prepatory panel meeting and review of available information |
| 11.30 | 12.30 | Interview with management<br>prof.dr. F. Picchioni Deputy programme director master (till 1.9.2016)<br>prof.dr.ir. M. Cao Deputy programme director master (from 1.9.2016)<br>dr.ir. G.H. Jonker Deputy programme director bachelor<br>drs. K. de Jonge Programme coordinator<br>drs. S. van Duin Academic advisor bachelor<br>M. Onrust, MSc Academic advisor master |
| 12.30 | 13.30 | Internal panel discussion (including lunch) |
| 13.30 | 14.15 | Interview with students BSc<br>T.S. Badings PPT / PTL 4th year<br>I.A.M. Bouwman PPT 2nd year<br>R.S. Janssen PTL 3rd year<br>S. Kanjanapornpreecha PTL 4th year<br>A.G.M. Peters PTL 4th year<br>J. Ruiter 1st year<br>Q.R.A. Swanborn PPT 4th year<br>G.M. van der Veen PPT 3rd year |
| 14.15 | 15.00 | Interview with students MSc<br>C.F. Jorna PTL 2nd year<br>W.H. Koek PPT 2nd year<br>W.A.W. Mulder PTL 4th year<br>W. Olsder PTL 2nd year<br>N. Stoffelsma PPT 3rd year<br>O.J. Strack van Schijndel PTL 2nd year<br>H. Trapnes PPT 1st year<br>T.C. Wesselink PTL 1st year |
| 15.00 | 15.30 | Internal discussion panel |
| 15.30 | 16.30 | Interview with academic staff BSc en MSc<br>prof.dr. B. Jayawardhana Lecturer, Discrete Technology and Production Automation<br>dr. ing. H. Kloosterman Lecturer, Design Group<br>prof.dr.ir. J.M.A. Scherpen Lecturer, Discrete Technology and Production Automation<br>prof.dr. M.J.E.C. van der Maarel Lecturer, Aquatic Biotechnology and Bioproducttechnology<br>dr. J. Yue Lecturer, Chemical Engineering<br>dr.ir. D.J. van der Zee, Lecturer FEB, Operations |
| 16.30 | 16.45 | Internal discussion panel |
| 16.45 | 17.30 | Interview with alumni<br>M. Akker, MSc PTL<br>M. Brühl, MSc PPT<br>N. Buurman, BSc PPT<br>N.L. Hartsuiker, BSc PTL<br>E.J. Heslinga, MSc PTL<br>M.E. Levenbach, MSc PPT<br>H.Z. Meijer, MSc PTL<br>T. Schnaar, BSc PTL |

| DAG 2 | | |
|---|---|---|
| 08.00 | 8.15 | Arrival panel at university |
| 8.15 | 8.45 | Site tour |
| 8.45 | 9.00 | Prepatory meeting panel |
| 9.00 | 9.30 | Interview with Educational Committee/Programme Committee<br>dr. A. Vakis Lecturer, Advanced Production Engineering/ Chair of the Programme Committee<br>dr. J. Krooneman Lecturer, Products and Processes for Biotechnology<br>dr. N.B. Szirbik Lecturer FEB, Operations<br>dr. P. Tesi Lecturer, Smart Manufacturing Systems<br>T.M. Kousemaker, BSc, Vice Chair Programme Committee, PPT, 2nd year Master<br>J.J.M. de Meyere PTL, 3rd year bachelor<br>A.J. Mollers PTL, 2nd year bachelor<br>T.G.J. Roelofs, BSc PTL, 2nd year master |
| 9.30 | 10.00 | Internal discussion panel |
| 10.00 | 11.00 | Interview with Board of Examiners<br>prof.dr. G.J.W. Euverink Lecturer, Products and Processes for Biotechnology/ chair of the Board of Examiners<br>dr. A.J. Bosch Lecturer<br>prof.dr.ir. M. Cao Member Board of Examiners till 1.9.2016*<br>drs. K. de Jonge Programme coordinator, secretary to the board<br>dr.ir. R. Dolfing External member Board of Examiners, Curriculum Developer and Teacher Trainer in Science & Engineering Education |
| 11.00 | 11.30 | Open office hour, this was not used. |
| 11.30 | 13.00 | Prepatory meeting for final interview (including lunch) |
| 13.00 | 14.00 | Final interview with management<br>prof.dr. K. Poelstra Vice dean of the faculty FMNS, education, programmes and teaching<br>prof.dr. P. Rudolf Director graduate school of science<br>prof.dr. R.G.E. Timmermans Director undergraduate school of science<br>prof.dr.ir. M. Cao Deputy programme director master (from 1.9.2016)<br>dr.ir. G.H. Jonker Deputy programme director bachelor<br>prof.dr. F. Picchioni Deputy programme director master (till 1.9.2016)<br>drs. K. de Jonge Programme coordinator |
| 14.00 | 16.30 | Formulating preliminary findings |
| 16.30 | 16.45 | Presentation of the preliminary findings |

* The new member of the Board of Examiners prof.dr. C. De Persis could not be present at the interview because of personal circumstances, therefore former member Prof.dr.ir. M. Cao replaced him.

# APPENDIX 6: THESES AND DOCUMENTS STUDIED BY THE PANEL

Prior to the site visit, the panel studied the theses of the students with the following student numbers:

*Bachelor's programme Technische bedrijfskunde*

| | | | | |
|---|---|---|---|---|
| 2222175 | 2025197 | 2073455 | 1768069 | 2102609 |
| 2042916 | 2037262 | 2357240 | 1853775 | 2004240 |
| 2401509 | 2265192 | 2057425 | 2356643 | 1885413 |

*Master's programme Industrial Engineering and Management*

| | | | | |
|---|---|---|---|---|
| 1525174 | 2193167 | 1793195 | 2237970 | 1683896 |
| 1785451 | 1812092 | 1784706 | 1535692 | 1945947 |
| 1701894 | 1538306 | 2041677 | 1732447 | 1453076 |
| 1475827 | 1926926 | 1990993 | 1574612 | |

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):
Course files Bachelor programme: - Semester 1.1: Orientation IEM - Semester 1.2: Physical systems for IEM - Semester 2.2: Outlining and implementing innovation strategy - Semester 3.1: Business System Design - Semester 3.2: Work Organization and Job Design
Course files Master programme: - Systems engineering (sem 2) - Sustainability for engineers (sem 2) - Track PPT: Interfacial Engineering (sem 1) - Track PTL: Analysis and Control of Smart Systems (sem 2)

Additional documents:

- Manual and student instructions Bachelor integration project
- Manual and student instructions Master Design project
- Manual and student instructions Master Research project
- Annual report Programme Committee 2015
- Annual report Board of Examiners 2015
- Minutes of the Board Examiners 2015-2016
- Report Industrial Advisory Board (31 May 2016)