RESEARCH ASSESSMENT

MECHANICAL ENGINEERING AND
INDUSTRIAL DESIGN ENGINEERING

UNIVERSITY OF TWENTE

Qanu
Catharijnesingel 56
PO Box 8035
3503 RA Utrecht
The Netherlands

Phone: +31 (0) 30 230 3100
E-mail: support@qanu.nl
Internet: www.qanu.nl

Project number: Q0781

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REPORT ON THE RESEARCH REVIEW OF MECHANICAL ENGINEERING AND INDUSTRIAL DESIGN ENGINEERING OF THE UNIVERSITY OF TWENTE

1. FOREWORD BY COMMITTEE CHAIR

In the fall of 2019 we were asked to carry out a research assessment of the Mechanical and Industrial Design Engineering (MIDE) departments of the Faculty of Engineering Technology at the University of Twente. The assignment was enthusiastically accepted by the committee members and visits and interviews were planned for the spring of 2020. But at that moment we were all surprised by an unknown and rapidly advancing virus that prevented the visits from taking place. In what turned out to be a naive thought, the visits were postponed until October 2020. Indeed, after a relatively quiet summer, the corona pandemic regained momentum in October, making international trips barely possible. In the end, it was decided to carry out the interviews and visits digitally.

MIDE did everything possible to make the interviews and the digital laboratory visits as efficient and pleasant as possible. And it succeeded very well. It was therefore all the more regrettable that we were not able to enjoy live the hospitality and friendly atmosphere that can spice up assessment visits. Nor were we able to enjoy informal contacts that also allow to soak up the general atmosphere of the campus. But even without these contacts a professional, but also a friendly, working atmosphere was quickly created within the committee and in the contacts between the committee and the UT staff. The jovial approach of Peter Hildering, secretary of the committee, certainly contributed to this. He thoroughly prepared the various aspects of the assessment and assisted the committee in a very professional way, not in the least when writing the final report. We are very grateful to him for that.

It was asked to assess the research programs of four departments of the Faculty of Engineering Technology. During two and a half days, the committee engaged in discussions with the Faculty and department management, the research staff, the researchers and PhD students in order to obtain additional information and especially to gain a better understanding of the content of the self-evaluation report. Because the discussions took place in a very open and transparent spirit, the committee was able to refine or validate its insights fairly quickly. The committee thanks all those who contributed to the creation of the self-evaluation report and to the organization of the virtual laboratory visits, as well as all those who participated in the interviews.

The committee was particularly impressed by the enthusiasm of the staff members and the pride with which they presented their achievements. The great freedom that the researchers at University of Twente are given to give own direction to their research, within the broader university framework, certainly lies at the base hereof. The committee particularly appreciates the fact that University of Twente and the Faculty of Engineering Technology have resolutely opted for a great deal of academic freedom and have consistently acted accordingly, even if this sometimes implies less clear strategic choices and a somewhat less pronounced coherence. The latter two are points where improvement is still possible.

Equally noteworthy and deserving is the sustained effort of the faculty to focus on applicable and applied research. In this way, it unmistakably lives up to its mission as an entrepreneurial faculty. The committee encourages the faculty not to abandon this path, but to support it even more strongly by giving more visibility to the fundamental research that ultimately underlies the applications.

Finally, the committee emphasizes that it has experienced these assessment activities, despite their completely digital character, as very successful, instructive and fascinating and wishes the Faculty of Engineering Technology and its staff a bright future.

Patrick De Baets
Committee chair

2. THE REVIEW COMMITTEE AND THE PROCEDURES

2.1. Scope of the review

The review committee has been asked to perform a review of research in Mechanical Engineering and Industrial Design Engineering conducted by the University of Twente. The review includes the four departments: Biomechanical Engineering (BE), Design Production and Management (DPM), Mechanics of Solids Surfaces and Systems (MS3), and Thermal and Fluid Engineering (TFE).

In accordance with the Standard Evaluation Protocol 2015 – 2021 (SEP) for research reviews in the Netherlands, the committee was asked to assess the quality, the relevance to society and the viability of the scientific research at the research unit as well as the strategic targets and the extent to which the unit is equipped to achieve these targets. Furthermore, a qualitative review of the PhD training programme, research integrity policy and diversity was part of the committee's assignment.

The Executive Board of the University of Twente provided the committee with Terms of Reference concerning the assessment. In this document, the Board asked the committee to pay special attention to and offer recommendations in the assessment regarding the following questions:

1. What is your opinion about the vision and mission and the resulting focus points of the faculty?
   - Is there a good match with the focus points of the departments?
   - Are there any areas in which we could excel that we are now missing?
   - Are there any areas that could better be terminated?
   - How do we handle 'new' research areas that don't (yet) fit within one of the research themes?
2. Is the current organizational structure suitable for achieving the goals, described in the vision and mission?
   - Do we miss research areas that are relevant for the vision and mission of the faculty?
   - How do we handle research that would fit in several departments?
   - Do the chosen positions in the Sectorplan fit into the departmental structure?
   - Is the current subdivision of departments good with respect to size and contents?
3. Quality
   - Do we use the right indicators for measuring quality?
   - Do we perform well according to these indicators?
   - Are the mechanisms to improve quality adequate?
4. What is your opinion about the level of ambition of the unit?
   - Considering the MIDE strategy and described research activities, what are appropriate targets regarding research quality and societal relevance of MIDE?
   - What is an appropriate target regarding number of PhDs supervised by the staff of MIDE?
   - What is an appropriate target in terms of acquired external funding (2nd and 3rd money stream)?

The committee discussed these aspects in an integrated manner during the site visit, which was organized online due to the COVID-19 measures limiting travel and in-person meetings, and described its findings in the report along the lines of the three SEP criteria. The questions are addressed implicitly or sometimes explicitly throughout the text. Due to the limited size and scope of the site visit, not all topics could be discussed in full-depth, yet the committee tried to include its input on the topics as much as possible.

2.2. Composition of the committee

The composition of the committee was as follows:

- Prof. Dr. Ir. Patrick De Baets (chair), dean of the Faculty of Engineering and Architecture, Ghent University;
- Prof. Dr. Paulo Jorge Da Silva Bartolo, department of Mechanical, Aerospace & Civil Engineering, University of Manchester;
- Prof. Dr.-Ing. Bernhard Peters, professor of Thermal and Fluid dynamics, University of Luxembourg;

- Prof. Dr.-Ing. habil. Marion Merklein, professor of Manufacturing Technology, Friedrich-Alexander-Universität Erlangen-Nürnberg;
- Prof. Dr. Jenny Dankelman, professor of Minimally Invasive Surgery and Intervention Techniques, Delft University of Technology;
- Ir. Vincent Ritman, director Research and Development Europe, Tata Steel;
- J. J. M. (Jeroen) Knippenberg MSc., former PhD student Mechanical Engineering, TU/e.

The committee was supported by Peter Hildering MSc., who acted as project coordinator and secretary on behalf of Qanu.

2.3. Independence

All members of the committee signed a statement of independence to guarantee an unbiased and independent assessment of the quality of the research performed by Mechanical Engineering and Industrial Design Engineering at the University of Twente. Personal or professional relationships between committee members and the research unit under review were reported and discussed at the start of the site visit amongst committee members. The committee concluded that no specific risk in terms of bias or undue influence existed and that all members were sufficiently independent.

2.4. Data provided to the committee

The committee received the self-evaluation report from the units under review, including all the information required by the SEP.

The committee also received the following documents:

- The Terms of Reference;
- The SEP 2015-2021;
- Lists of publications, consisting of five key publications per unit
- An overview of staff, output and funding per department
- Overviews of patents, funded projects, awards and prizes and memberships
- Scrapbooks of MIDE research & Tenure Tracker interviews

2.5. Procedures followed by the committee

The committee proceeded according to the SEP. Prior to the first meeting, all committee members independently formulated a preliminary assessment of the units under review based on the written information that was provided prior to the site visit. The final review is based on both the documentation provided by the Department and the information gathered during the interviews with management and representatives of the research unit during the site visit. The online site visit took place on 7, 12 and 13 October 2020 (see the schedule in Appendix 2).

Preceding the interviews, the committee was briefed by Qanu about research reviews according to the SEP. It also discussed the preliminary assessments and decided upon a number of comments and questions. The committee also agreed upon procedural matters and aspects of the review. After the interviews the committee discussed its findings and comments in order to allow the chair to present the preliminary findings and to provide the secretary with argumentation to draft a first version of the review report.

The draft report by the committee and secretary was presented to the University of Twente for factual corrections and comments. In close consultation with the chair and other committee members, the comments were reviewed to draft the final report. The final report was presented to the Board of the University and to the management of the research unit.

The committee used the criteria and categories of the Standard Evaluation Protocol 2015-2021 (SEP). For more information see Appendix 1.

3. ASSESSMENT OF MECHANICAL ENGINEERING AND INDUSTRIAL DESIGN ENGINEERING

The research unit Mechanical Engineering and Industrial Design Engineering (MIDE) consists of four research departments within the Faculty of Engineering Technology of the University of Twente: Biomechanical Engineering (BE), Design, Production and Management (DPM), Mechanics of Solids, Surfaces and Systems (MS3) and Thermal and Fluid Engineering (TFE). The fifth department within the Faculty, Civil Engineering (CE), is separately evaluated.

3.1. Mission, vision and strategy

The University of Twente aims to be an entrepreneurial university that combines social and technological disciplines. It operates under the motto High Tech – Human Touch. The Faculty ET connects to this mission by aiming

> *'to generate fundamental knowledge of engineering technology, and translating this knowledge into solutions for complex and multidisciplinary technical problems in order to solve societal challenges'*.

Within the context of this mission, MIDE focuses on the integrated value chain, which is the initiation, formulation, design and development of technical solutions for current and future societal challenges. Multidisciplinarity is key in this strategy. In the past years, MIDE has focused on creating a multidisciplinary research environment by clustering research chairs in the current four multidisciplinary research departments around a central topic. Other efforts include opening specific tenure track positions for cross-departmental topics, defining faculty-wide multidisciplinary research themes and participating in cross-departmental research programmes and research institutes.

Interdepartmental and interfaculty cooperation within the University are pursued through research institutes and research centres. Research institutes are large, university-wide strategic programmes with the associated facilities. MIDE researchers are involved in TechMed (health care technology), MESA+ (nanotechnology) and the Digital Society Institute (human-centred digital society). Smaller initiatives for internal collaboration are research centres, cooperative research programmes that can take various forms, ranging from joint projects to actual labs, such as the DesignLab.

As the unit aims to translate engineering knowledge into solutions for societal challenges, external collaborations are essential. MIDE aims to be a preferred partner for governments, industry and academics worldwide. It aims to be involved in national and international collaborations, and maintains structural links with industry on a regional, national, European and global level. MIDE strongly encourages such collaborations in order to disseminate research findings and gain insight into the knowledge demands from practice. Furthermore, MIDE has installed an Industrial Advisory Board and an International Scientific Advisory Board in response to recommendations of the previous research review. These Boards are regularly consulted to align the priorities of MIDE with that of academics and industry.

The committee has studied the mission and vision of MIDE, and strategy of the past years, and concludes that they are clear and consistent. The Faculty's mission and vision clearly align with those of the university at a central level, showing a strong focus on translation of fundamental knowledge into solutions for multidisciplinary technical problems. The unit has demonstrably achieved the strategic priorities set earlier. This includes a successful reorganization of the research departments into multidisciplinary teams and a further strengthening of its national and international collaborations. The research institutes and centres are good structures to enhance multidisciplinary research and improve internal collaboration. The committee praises MIDE for this. It thinks that this has brought the unit in a position to further expand its ambitions by defining focused targets and priorities, and identifying opportunities that align with the strength of the unit. This will be further discussed under Viability.

3.2. Governance and management

MIDE is not a formal organizational entity, but is governed by the Management Team (MT) of the Faculty, which covers all research departments. The MT is chaired by the Dean of the Faculty, which furthermore consists of the director of operations, the vice-dean research, the vice-dean education and a student assessor. The MT is responsible for determining and implementing the vision and strategy of the Faculty, including investments in staff and equipment, and alignment of research areas.

Departments consists of five (TFE) to twelve (MS3) research chairs, which include a full professor, associate and assistant professors, postdoctoral researchers and PhD students. Each department is headed by a department chair, who is selected from within and by the research chairs of the department, and represents the department as a *primus inter pares* in various contexts. Furthermore, all research chairs within the Faculty are united in the Chamber of Professors, an informal entity that meets four times per year with the MT to exchange information and views.

The committee has discussed this governance and management of the unit with various representatives of the Faculty and departments during the site visit. It concludes that the governance model has a bottom-up rather than a top-down character. The MT aims to implement its vision by seeking support and consensus among the research chairs, and by creating incentives such as extra funding and research positions that align with its vision. The committee noted from the interviews that the research chairs very much value this academic freedom. The chairs and research departments have a relatively large amount of freedom to form their own research agendas, which results in dynamic research departments with involved members. On the other hand, this model can hinder the effective deployment of the faculty strategy, resulting in a slow adaptation with regard to new priorities.

The committee respects and understands the decision of the Faculty to govern in a bottom-up model with a large degree of autonomy for the research chairs. It however thinks that within this model, there is still room for improvement. It notes for instance that there is gap between the MT and the research chairs. Decisions and priorities of the MT are directly conveyed to the individual research chairs, which is a large and heterogeneous group. Considering that the departments are relatively new organizational entities, the committee understands where this model comes from. However, given this new structure, it would make sense to treat the departments as organizational units with a strategic role. The department chairs could then bridge the gap between faculty management and research chairs by involving them more structurally in strategic discussions, or even by including them in the MT. As this would transform the department chair position into a more leadership role, a period of appointment longer than the current two years could be considered for department chairs in order to guarantee continuity of leadership.

For the research departments to function as coherent units, it is important that they share a mission and vision. The committee discussed this with the individual departments, and noted that some departments already strongly invested in developing a shared mission and strategy. The DPM department for instance, which shared with the committee an inspiring vision to be a domain integrator, bringing various disciplines together in order to create the optimal product development. According to the committee, such a shared vision is important to be able to function as a coherent, strategic unit. During the site visit, the committee also discussed the optimal size of the research departments. The committee thinks that there is not necessarily an optimal size, as long as sufficient common ground can be found. If this is not the case, the department has a risk of falling apart into multiple smaller units. The panel recommends the departments to keep investing in a shared vision, and the faculty management to determine the optimal size of the individual departments based on their internal coherence.

3.3. Research quality

To determine the research quality of the unit, MIDE considers a number of key performance indicators, including research output in the form of peer-reviewed articles, the use of research products and recognition from peers.

The committee studied these performance indicators for the four research departments and concludes that the unit has a solid output with regard to these indicators. In particular, the unit publishes articles in relevant journals in the field as well as conference papers on respected conferences, which are often used by peers as demonstrated by citations. Researchers from within the unit have received recognition from peers, for instance through external research funding (among others 1 Veni, 3 Vidi and 1 Vici grant, 2 ERC Starting, 1 Consolidator and 1 Proof of Concept Grant), and involvement in various international scientific committees and associations.

The committee does note that the attention of the unit sometimes tilts towards applied research rather than fundamental research, which can for instance be seen in the large number of publications via conference papers rather than journal papers. Although this is useful for reaching industrial partners, with regard to improving its research quality the unit could benefit from more emphasis on refereed journal papers. These tend to be more impactful and better accessible than conference papers within the field. According to the committee, the strong applied research of the unit (see Relevance to society) creates a challenge to keep fundamental research within MIDE up to the same level, as the mission of MIDE requires fundamental research to be translated into application. With the large successes and opportunities of MIDE's applied research, there is a risk that fundamental research disappears more into the background. The unit also recognizes this, as demonstrated in the efforts to keep investing in publishing journal papers and applying for personal grants for fundamental research. The committee supports this strategy and urges the unit to keep up its efforts in this aspect.

For the *Biomechanical Engineering* department, the committee found that they are successful in combining fundamental, technological and medical research. The research themes of the department, namely neural, movement and tissue mechanics, fit well with the multidisciplinary approach of the Faculty, as they integrate (robotic) mechanical engineering and clinical research. Despite the growth in the past year, the BE department is still the smallest department. Nevertheless, the department has managed to acquire large number of grants and specifically personal grants, which is a good indication of quality of their research and the capability of attracting excellent researchers, as well as a large number of PhD students. Compared to the other departments, its output strategy already focuses more on journal articles than conference papers, fitting the goals of the faculty overall.

The *Thermal and Fluid Engineering* department clusters the research chairs in the field of thermodynamics and fluid dynamics. It has a multidisciplinary approach, bridging disciplines to tackle complex problems in both fundamental science and engineering. It has solid output and funding, and has strong ties with industry both in terms of output and funding. The department has grown substantially in recent years, although it is hard to fill vacancies. The field is very competitive, especially for talented senior researchers. The unit has however succeeded in hiring talented tenure track researchers, and expects that they will be able to develop into full professors. To maintain the quality of its research, the department indicates that it needs more lab space, for which it is currently exploring options with the Faculty.

The *Mechanics of Solids, Surfaces and Systems* is the largest of the departments, and result from a fusion of ten existing research chairs and two new chairs. As a result, it has the broadest focus of the departments, focusing on many different topics in the interplay between materials, production and products. The department has a solid output of peer reviewed journal papers and conference contributions, which is in line with international benchmarks. The department mostly relies on contract research next to its direct government funding, but it has also successfully obtained research grants. The department has state of the art research facilities (such as a laser lab, a mechanical testing lab, a microscopy lab, a tribology lab, a mechanics and robotics lab and a dynamics lab). With regard to its academic network, the department is founder of the "Thermoplastic composites Research Center" (TPRC), and of the "Elastomer Competence Center (ECC)", a collaboration with the Polymer Science Park.

The *Design, Production and Management* department focuses on key aspects of the overall life cycle of products and production (sustainable design and manufacturing) with a significant potential to bridge the research activities conducted by several other departments. Additive manufacturing is one of the key enabling technologies for the department, which integrates several academics internationally recognized as experts in the field. Several academics are also members of the International Academy for Production Engineering (CIRP), which is the world leading organization in production engineering research, at the forefront of design, optimization, control and management of processes, machines and systems. The academy has a restricted membership based on demonstrated excellence in research, which shows the quality of the research conducted by some members of the department. The department has a solid output of peer reviewed journal papers and conference contributions, book chapters and books, which is in line with international benchmarks. The level of funding and industrial collaborations is commendable and it is expected to increase in the near future due to the recently established Fraunhofer Project Centre, which will also contribute to both the national and international visibility of the department.

The committee found the full list of key performance indicators quite extensive, and thinks that together they paint a full picture of the research quality by MIDE. In the analysis, it however missed strategic priorities, as well as quantitative or qualitative targets with regard to most of these indicators. It is therefore hard to determine, both for internal and external quality assurance, whether the unit fulfils its own ambitions. The committee recommends to prioritize the key performance indicators, and formulate at least minimum requirements for each of these indicators. The unit has for instance done this with research grants, where it aims to obtain at least 4 grants per year in either the Veni/Vidi/Vici or ERC schemes. The committee stresses that these should not necessarily be quantitative targets: but rather ambitions with regard to quality and impact. To formulate appropriate targets, it might be helpful to regularly benchmark the unit to similar departments or universities, for instance with help of the members of the Scientific Advisory Board.

3.4. Relevance to society

To determine the societal relevance of the unit, MIDE considers a number of key performance indicators. The most important indicators are cooperation with industry and (prototypes of) products. This ties in with the mission of the unit to translate fundamental knowledge into engineering solutions for complex problems. Other indicators include spin-off companies, patents, outreach activities and the training of academically qualified engineers.

The committee studied these performance indicators for the four research departments, and concludes that the unit performs very well in these aspects, and has an excellent track record in applied research. The unit has many collaborations with industry and other societal partners. Prominent cooperations are through the Fraunhofer Project Centre (FPC@UT), a joint endeavour between the UT and the German Fraunhofer-Gesellschaft, which currently manages 40 projects between academics and companies. The Faculty also has links with many industrial partners through contract research, which amounts to 39% of its funding. Major partners include ASML, Thales, Tata Steel, Continental, Siemens, Volkswagen, Shell, Ten Cate, Boeing, Apollo Vredestein, the Dutch Railways, Asahi Kasei and many more. Some labs are also used by industry, such as the Decision Making lab, in which group interaction can be studied, the wind tunnel and the VR and Smart Industry lab. It has developed products and prototypes for many applications, such as dry grip behaviour of tires, models for sound absorption of road surfaces, high-tech seats for business jet and a robotic gait trainer that assists the walking pattern during rehabilitation. The unit has furthermore launched 14 spin-off companies in the past six years, and filed 17 patents in university ownership.

For the *Biomechanical Engineering* department, the committee noted the many collaborations with commercial and clinical partners. Part of the researchers have dual appointments at the departments and hospitals or in industry, and there is a heavy involvement of external partners in projects. The department has strong ties with clinical centres Medisch Spectrum Twente, UMC Groningen, Roessingh, Hannover Medical School and Uniklinik RWTH Aachen, and industry leaders such as Philips Healthcare and Siemens. The biomedical robotics research, in which the department is increasingly specializing, is an attractive field for societal and commercial applications.

The *Thermal and Fluid Engineering* department TFE has worked on many impressive applications with industry in recent years. These include a system to secure liquid lads in tank trucks, contributing to a safer transport in conjunction with fuel as it prevents tank trucks from tipping over, which is currently manufactured by the company Accede. The department also owns a core patent to produce foams through AM. The manufacturing method allows to make foams for improved materials for heat storage, carbon-dioxide capture, and noise-insulation, and is a promising candidate for commercialization, according to the committee. TFE is also the open-source code provider for the software platform MercuryDPM (MercuryDPM.org) which is an excellent contribution to the community and is commercialized through the MercuryLab spin-off.

The *Mechanics of Solids, Surfaces and Systems* department has many structural partnerships with companies such as ASML, Tata Steel, Philips, Shell, NXP, SKF, VDL, Boeing and TenCate. The strong links with industry are also illustrated by the dual appointments of different staff members. The department follows a strategy of valorization whenever possible. It is holder of five patent applications, can show the world first certified 3D printed off-shore product (a ship propeller), is co-developer of a high-performance microtome cutter (ThermoFischer Scientific) and has developed the world's smallest 3D free-standing laser printed golden helix using Laser-induced Forward Transfer (LIFT).

The *Design, Production and Management* department addresses key social and environmental challenges aiming to develop more efficient products and production systems, using less resources and energy and covering key strategies of mass customization and mass personalization. According to the information provided by the department, 50% of its research is funded and conducted in partnership with industry, which is a good indicator of the potential economic impact of the department. Research activities are interdisciplinary as demonstrated by the projects developed at the DesignLab and the Fraunhofer Project Centre. The latter opens new possibilities for knowledge and technology transfer reinforcing the links between the department and industry.

In the light of the mission of the Faculty, the committee considers the key performance indicators fitting. It does recommend, as also mentioned under Research Quality, that the unit could benefit from prioritizing and setting targets. The additional performance indicators that the Faculty listed, such as outreach activities, public prizes and patents, are not equally important to the mission of the unit as industrial cooperations, prototyping and products. This became clear from the interviews, but was not obvious from the descriptions.

Finally, the committee recommends the unit to also consider their contributions to society in a broader sense. The vision and strategy of the Faculty is of a practical nature, which the committee understands and respects, but on the other hand, its mission also states that the unit ultimately aims to address societal challenges. The committee challenges the unit to envision their role in broader, societal terms. This could for instance be in terms of the Sustainable Development Goals of the United Nations or another formulation of societal challenges. Such an exercise might give new insights on the vision and priorities of the unit as a whole.

3.5. Viability

In the coming years, MIDE aims to further strengthen its national and international position as a preferred partner in innovation in the integrated value chain. As a result of growing student numbers and additional funds through the Sectorplan Techniek, there is room for expansion in the various departments. The Faculty is developing strategic choices to direct this expansion. It wants to reinforce the strength of MIDE by investing in three domains in which the unit currently excels, namely Sustainable Energy (transport, conversion and storage of heat), Intelligent Manufacturing (manufacturing of functional material systems and next generation structural materials) and Robotics for Personalized Heath Care (smart supporting robots). Furthermore, MIDE has developed future targets and priorities to make this investment a success. These include stimulating an entrepreneurial mind-set and behaviour,

develop state-of-the-art facilities, but also to improve research quality by pursuing personal grants and improving the attention towards research journal publications.

The committee has studied the future targets and plans of the unit, as well as the SWOT analysis provided. It concludes that the plans of the unit for future investments are solid. The research focal points are relevant and play into the strength of the unit's research. For Sustainable Energy, the committee sees promise in a broadening the theme towards a cross-departmental topic Sustainability, which could not only cover energy research but also for instance sustainable products and production processes.

The future targets and priorities paint a good picture of what the unit wants to achieve in the next period. They are well-aligned with the mission, vision and strengths of the unit, as well as with the opportunities and threats described in the SWOT. The committee thinks that the targets could be better defined and focused on specific priorities. A good example is the further development of a research centre for robotics that was discussed during the site visit. This is a clear priority relevant to the achievement of the unit's strategy. Another example is the intended increase in personal grants by providing support in writing proposals. Defining more of such activities could help to concretize how to achieve the strategic targets. The same applies to the SWOT analysis, which misses a final step in translating the opportunities and threats in concrete steps to be taken to address these. The committee suggests that the target and priorities should be discussed among the senior researchers of the department, as well as the Scientific and Industrial Advisory Boards, resulting in clear, broadly supported steps to take in the coming years.

Adding to the threats and opportunities identified by the unit, the committee adds that there seems to be an opportunity to attract industry funding for research facilities. The unit is currently experiencing a shortage of lab space, which will further increase with the projected growth, and relatively high overhead costs. At the same time, the facilities are highly appreciated and sometimes also used by industry. The committee thinks that there is a realistic opportunity that companies might want to invest in shared facilities, and recommends the unit to investigate this.

During the site visit, the unit discussed with the committee how it could better increase its visibility to show external academic, industrial and societal partners what its researchers have to offer. According to the committee, this comes down to determining the unique selling points of the unit, where it excels compared to other universities internationally, and profile on these areas in its external communication. The committee suggests that smart manufacturing might be such a unique selling point. According to the committee, the unit's expertise in this field with regard to additive manufacturing, robotics, virtualization and AI cannot be matched internationally. There are possibly other fields, subfields or applications areas such as this that the unit could identify with help of the Scientific and Industrial Advisory Board.

3.6. PhD programmes

The Faculty distinguishes between PhD students and PDEng students. A PDEng is a Professional Doctorate in Engineering, consisting of a two year full-time technological designer programme. Roughly half of this period is spent on an innovative technological design project at a company or in the public sector. MIDE is involved in PDEng programmes on Energy and Process Technology, Maintenance and Robotics.

PhD/PDEng education and supervision

The Doctorate Board of the University is responsible for the doctorate programme, and organizes the PhD/PDEng education and supervision through the university-wide Twente Graduate School (TGS). All PhD and PDEng candidates of the university are enrolled in TGS. It requires candidates to obtain the equivalent of 30 EC (PhD) or 51 EC (PDEng) in courses in in-depth subject-specific courses, academic skills and career orientation, in roughly equal parts. The PhD/PDEng candidates decide together with their supervisors which courses are necessary for the development of the candidate, using the exit qualifications of the TGS as starting point. Courses can be chosen from

the offer by the UT Centre for Training & Development, but also through national research schools or doctoral schools, or can take the form of attending conferences and summer schools. A small selection of courses is mandatory, and includes research ethics and general academic skills.

At the start of each PhD/PDEng trajectory, the student draws up a training and supervision plan with his/her supervisor. This includes a description on what knowledge and skills should be acquired by the candidate, the frequency and quantity of the supervision (in hours per month) and a data management plan. This plan is administered in a dedicated trainee monitoring system (Hora Finita). There is a formal evaluation after six to nine months,, the Qualifier. The candidate presents the progress of his/her programme and proposes activities for the remaining period. The qualifier committee, which also includes an external member, determines whether the scientific quality of the work is sufficient, and whether the candidate is expected to successfully complete their project. If the result is insufficient, the candidate is offered an improvement period of three months. After a second insufficient Qualifier, the project is discontinued.

The candidates that the panel interviewed were generally satisfied with their PhD/PDEng education and supervision. The courses offered provide plenty of opportunities for career orientation, development of skills and personal development. They feel well supported by their supervisors. Based on these comments and an overview of the PhD Education it studied, the committee is positive on the content of the PhD/PDEng education and the supervision. The courses are varied and offer candidates to develop themselves in the direction their supervisors and themselves think is necessary. The committee considers the go/no-go decision before the end of the first year a good mechanism for quality check and early detection of problematic projects. In terms of additions to the PhD education, the PhD candidates did suggest that there could be more opportunities for peer learning, for instance between starting and more experienced PhD candidates. They felt that such contacts could have helped them get better through the first two years. The committee recommends to investigate whether this can be arranged.

Completion and success rates

The Faculty expects its full-time PhD candidates to complete their thesis within four years, and PDEng candidates in two years. Until 2018/2019, approximately 10-15% of the PhD candidates met this target. After five years, 40-50% of PhD students is finished, and after six years this is 60-70%. The remaining group either dropped out earlier or is still not finished after six years. For PDEng students, the success rates are higher: roughly 50% finishes on time, and after 2.5 years, 80-85% has completed his or her work. This data does not yet reflect the effect of measures taken after 2018/2019 (see below).

The Faculty is not satisfied with the success rates of PhD candidates, and names this a point of concern. The committee shares this feeling and discussed this with the management of the unit, supervisors and PhD students. The Faculty management reported to the committee that they think that PhD candidates need more guidance to help them finish their thesis on time. There has long been a culture in the Faculty that timely completion of a thesis is of secondary importance, and can be delayed to allow for additional research. Recently the Faculty and the university have taken several measures to counter this. PhD candidates no longer receive an extension of their contract after 4 years, except for personal circumstances, to give a strong message to both supervisor and candidate that the research should be completed in the contractual time. Next to the earlier mentioned supervision plan at the start of the project and the Qualifier, all PhD candidates are monitored by the Graduate School during the entire process through Hora Finita. This system registers the progression of each candidate, and the agreements made between the candidate and supervisor. This system was implemented in 2019, and is expected by the Faculty to prevent undetected delays in the progression of PhD students. The PhD students and supervisors that the panel interviewed shared this expectation. They reported that it helps them develop a long-term planning, for instance by starting to write papers that could serve as thesis chapter early in the process. It also helps to equalize differences in supervision between departments, which some PhD students experienced, with some requiring a set number of publications before graduation and others leaving it more open.

The committee approves of the measures taken by the Faculty to stimulate thesis completion. It was in particular impressed by the active monitoring of PhD students by the Graduate School, which might be instrumental in improving the success rates. The committee furthermore noted that the Graduate School offers a course in project management specifically focused on the thesis trajectory. Considering the concerns that the Faculty has with regard to success rates, the committee was surprised to find out that this course was optional. It recommends to make project management a mandatory course for starting PhD students.

Quantity of PhD students
The Faculty also requested the committee to assess the quantity of PhD students within the unit. The committee considers the current number of PhD students to be fitting, but notes that they are not equally distributed among the departments. This suggests that some departments could be more ambitious in attracting PhD students. The efforts to pursue personal grants might address this, as this often includes the opportunity to invest in PhD students for fundamental research.

3.7. Research integrity

The university has several policies and procedures in place aimed at safeguarding research integrity within the university. This includes a code of conduct for integrity applicable to all researchers and a Scientific Integrity Complaints Procedure to report suspicions of scientific misconduct. Furthermore, the Faculty has an elaborate data management policy, consisting of measures to prevent loss of research data, archiving data after completion of a research project, rules for adding meta-data to research data to stimulate re-use. Each PhD student follows a mandatory research data management course and writes a data management plan for his/her own research project. Each research group is responsible for developing its own specific research data management policy based on the rules provided by the Faculty.

When discussed during the site visit, research integrity appeared to be well-embedded in the culture of the unit. The regulations for research integrity, report of misconduct and data management were recognized and applied by the various participants in the interviews. The committee was impressed by the very solid policies and well-organized implementation of these within the Faculty, and praises the unit for this.

3.8. Diversity

The Faculty aims to be a diverse research environment in order to achieve a variety of different perspectives and opinions. The research groups are a mix of various nationalities, with more than half of the staff being non-Dutch (of which one third is European and two-third non-European). Of the PhD students, three-quarters are non-Dutch. To facilitate this international workplace, the university invests in extra support for new international staff, cultural awareness training for all staff, and a coaching system for new non-Dutch staff. The committee agrees that the unit has a very internationally diverse composition, and praises the initiatives taken by the Faculty to promote a fruitful multicultural workplace.

With regard to gender diversity, the Faculty aims to have at least 35% female staff. Currently, this percentage is at 19%. There are various policies in place to improve this percentage, including a number of female-only vacancies, a requirement to include at least 30-50% of female candidates on the shortlist for other vacancies, and an incentive fund to accelerate the career of talented female researchers. As pilot, the university has also appointed an inclusion officer. The committee agrees that the current gender balance should be improved, and appreciates the measures taken to this end. It thinks that positive discrimination until the target is reached is appropriate. It encourages the Faculty to keep up the efforts, as the target is not yet in sight. The committee suggests to increase attention towards inclusion in the management by adding a vice-dean of inclusion to the MT, or give one of the MT members this role.

3.9. Conclusions

MIDE aims to translate fundamental knowledge of engineering technology into solutions for complex, multidisciplinary technical problems in order to solve societal challenges. The research quality of the unit is *very good*. Its researchers publish articles in relevant journals as well as conference papers on respected conferences, are embedded in academic networks within the field, attract external research funding and are equipped with state-of-the-art research facilities. The societal relevance of the unit is *excellent*. MIDE has many ties to companies, which provide relevant research questions and the associated funding. Results regularly take the form of concrete products or prototypes, which are often commercialized by partners or spin-off companies. This fully realizes the mission of the unit to translate knowledge into solutions. With the focus on its excellent applied research, the challenge for the unit is to keep its fundamental research up to the same level. The unit recognizes this and is putting additional effort in publishing in peer-reviewed journals and attracting personal grants for fundamental research. The committee encourages this.

The viability of the unit is *very good*. MIDE has a clear vision of what it wants to achieve in the future and is well-equipped to pursue these goals. The recent reorganization of the Faculty has created a multidisciplinary research environment, and the research institutes and centres in which MIDE participates adds to this. The unit has viable staffing and funding, and can expect further growth in the future. With this growth, need arises for additional facilities, which is already a point of discussion with the University and Faculty. The committee has full confidence that this will be solved. The unit could be more concrete with regard to its ambitions, priorities and strategy. This applies to both the priorities and targets with regard to research quality and scientific relevance, as well to the means with which the unit aims to achieve its future strategy. The committee thinks that the bridging of the gap in management between the research chairs and faculty management could help with the deployment and implementation of strategy, for instance by giving the department chairs a larger role in the management of the Faculty.

The unit has a solid PhD/PDEng programme in place and pays attention to issues of research integrity. The composition of the research staff is very international. The gender balance could be improved, an issue of which the unit is aware and is taking measures for improvement.

3.10. Overview of the quantitative assessment of the research unit

After having assessed the research quality, relevance to society and viability, and comparing that to the developments and standard in the field of Mechanical Engineering and Industrial Design Engineering, the committee comes to the following quantitative assessments:

Research quality:	very good
Relevance to society:	excellent
Viability:	very good

4. RECOMMENDATIONS

Considering the SEP evaluation protocol and the Terms of Reference provided by the University of Twente, the committee recommends unit Mechanical Engineering and Industrial Design Engineering to:

- Balance academic freedom with increased coherence and strategic strength of the research departments. Keep investing in a shared vision within the departments, and involve the department chairs more structurally in strategic discussions, for instance by including them in the MT.
- Consider a period of appointment longer than two years for the department chairs to guarantee continuity of leadership.
- Keep focusing on safeguarding high-level fundamental research, and keep pursuing personal grants for fundamental research and an increased output in academic journals to achieve this.
- Envision the contributions of the unit towards grand societal challenges, for instance using the 17 Sustainable Development Goals of the United Nations as a stepping stone.
- Consider broadening the Sustainable Energy theme towards a cross-departmental topic Sustainability.
- Prioritize goals and ambitions for research quality and societal relevance, and set qualitative and/or quantitative targets to pursue. Regular benchmarks with other institutions and consultation of the external Boards might be useful during this process.
- Focus the strategic targets of the unit on specific goals and priorities, and the steps to take in order to achieve those goals. Involve senior researchers within the unit and the external Boards in these discussions. The comprehensive SWOT analysis is a good start for identifying priorities and actions.
- Explore opportunities for investments by companies in shared facilities.
- Determine unique selling points of the unit and profile on these points to increase visibility of the unit. One candidate for such a unique selling point might be smart manufacturing.
- Investigate whether peer learning opportunities between starting and more experienced PhD students can be organized and added to the PhD educational programme.
- Keep working on improving the success rates of PhD students. Making the project management course mandatory for starting PhD students might be helpful to this end.
- Keep up efforts to improve the gender balance within the institute. A way to increase attention to this topic could be to create a vice-dean of inclusion, either as addition to the MT or as extra role of a sitting MT member.

APPENDICES

APPENDIX 1: THE SEP CRITERIA AND CATEGORIES

There are three criteria that have to be assessed:

- Research quality:
  - Level of excellence in the international field;
  - Quality and Scientific relevance of research;
  - Contribution to body of scientific knowledge;
  - Academic reputation;
  - Scale of the unit's research results (scientific publications, instruments and infrastructure developed and other contributions).

- Relevance to society:
  - Quality, scale and relevance of contributions targeting specific economic, social or cultural target groups;
  - Advisory reports for policy;
  - Contributions to public debates.

The point is to assess contributions in areas that the research unit has itself designated as target areas.

- Viability:
  - The strategy that the research unit intends to pursue in the years ahead and the extent to which it is capable of meeting its targets in research and society during this period;
  - The governance and leadership skills of the research unit's management.

Category	**Meaning**	**Research quality**	**Relevance to society**	**Viability**
1	World leading/excellent	The unit has been shown to be one of the most influential research groups in the world in its particular field.	The unit makes an outstanding contribution to society	The unit is excellently equipped for the future
2	Very good	The unit conducts very good, internationally recognised research	The unit makes a very good contribution to society	The unit is very well equipped for the future
3	Good	The unit conducts good research	The unit makes a good contribution to society	The unit makes responsible strategic decisions and is therefore well equipped for the future
4	Unsatisfactory	The unit does not achieve satisfactory results in its field	The unit does not make a satisfactory contribution to society	The unit is not adequately equipped for the future

APPENDIX 2: PROGRAMME OF THE ONLINE SITE VISIT

Wednesday 7 October	**MS Teams meeting**
10.00 - 12.00	Preparation / Committee in private
14.00 - 14.30	Department DPM / Subprogramme Design, Production & Management
14.30 - 15.00	Department MS3 / Subprogramme Mechanics of Solids, Surfaces and Systems
Recap	Committee in private

Monday 12 October	**MS Teams meeting**
15.00 - 16.00	Preparation / Committee in private
16.15 - 17.15	Formal welcome and meeting with University and Faculty Management

Tuesday 13 October	**MS Teams meeting**
08.30 - 09.00	Preparation / Committee in private
09.00 - 09.30	Management ET
09.45 - 10.15	Department BE / Subprogramme Biomechanical Engineering
10.30 - 11.00	Department TFE / Subprogramme Thermal and Fluid Engineering
11.15 - 11.45	Tour of the facilities
12.00 - 13.00	Formal interview with PhD students / Tenure Trackers
13.15 - 14.00	Second session Management ET
14.00 - 15.45	Committee review of the visit (in private)
16.00 - 17.00	Feedback to Faculty

APPENDIX 3: QUANTITATIVE DATA

Table 2 Composition of research staff at level of the four MIDE departments

	2013		2014		2015		2016		2017		2018	
MIDE all	**#**	**Fte**	**#**	**Fte**	**#**	**Fte**	**#**	**Fte**	**#**	**Fte**	**#**	**Fte**
Scientific staff (1)	98	29.83	99	29.97	94	27.58	88	26.94	97	28.19	106	31.72
Post docs (2)	68	30.22	67	25.38	81	29.45	78	29.04	95	33.81	115	41.75
PhD students (3)	162	85.47	130	71.88	138	74.38	137	79,74	164	94.4	185	101.21
Total research staff	**311**	**145.52**	**281**	**127.23**	**299**	**131.41**	**292**	**135.72**	**337**	**156.40**	**377**	**174.68**
PDEng	6	3.16	10	4.89	13	7.27	24	13.53	23	14.97	26	12.20
Supporting staff (4)	16	7.50	18	8.23	19	8.89	22	10.20	22	10.53	23	10.24
Visiting fellows	1	1	2	2	4	4	1	1	2	2	5	5
Sum	**334**	**157.18**	**311**	**142.35**	**335**	**151.57**	**339**	**160.45**	**384**	**183.9**	**431**	**202.12**

Note 1: Comparable with WOPI categories Professor (HGL), Associate Professor (UHD) and Assistant Professor (UD); tenured and non-tenured staff
Note 2: Comparable with WOPI category Researcher (Onderzoeker)
Note 3: Standard PhD (employed) and Contract PhDs (externally or internally funded but not employed)
Note 4: Technical staff and Educational & research staff (50% research, 50% education)

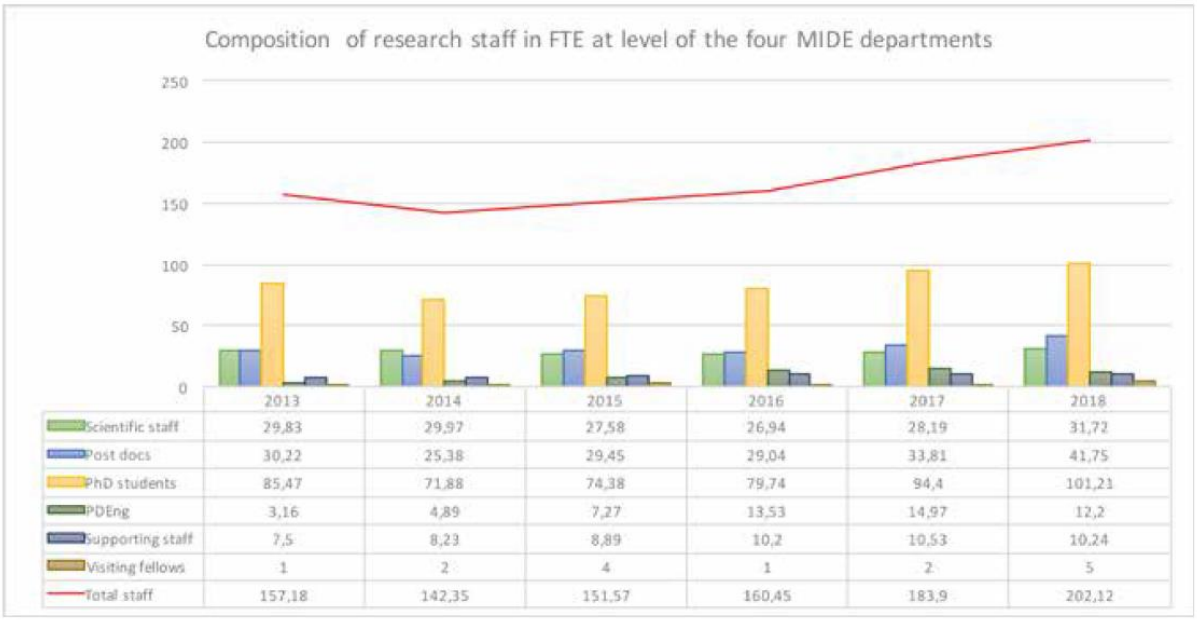

Table 3 Funding at level of the 4 MIDE departments within MIDE.

	2013		2014		2015		2016		2017		2018	
Funding	**k €**	**%**	**k €**	**%**	**k €**	**%**	**k €**	**%**	**k €**	**%**	**k €**	**%**
Direct Funding	10982	45	10616	49	11110	50	11515	51	14058	54	14366	53
Research Grants (1)	1427	6	1932	9	2806	13	2826	12	3000	11	3412	12
Contracts incl. Indirect Funding (2)	11783	49	9269	42	8190	37	8537	37	9137	35	9574	35
Total funding	**24192**	**100**	**21817**	**100**	**22106**	**100**	**22878**	**100**	**26195**	**100**	**27352**	**100**
Expenditure	**k €**	**%**	**k €**	**%**	**k €**	**%**	**k €**	**%**	**k €**	**%**	**k €**	**%**
Personnel Costs	16543	68	15250	64	15545	68	15997	72	17359	68	19653	69
Housing Costs	2343	10	2119	9	2196	10	2038	9	1992	8	1947	7
Other Costs	5487	23	6569	27	4963	22	4235	19	6147	24	7005	24
Total Expenditure	**24374**	**100**	**23938**	**100**	**22704**	**100**	**22270**	**100**	**25498**	**100**	**28605**	**100**

Note 1. Research grants are grants from the national science foundations (NWO, STW, FOM).
Note 2. Contract research includes funding from agencies from Dutch ministries (Agentschap.nl, M2I), EU projects and projects directly sponsored by industrial partners
Note 3. All amounts in k€. Components may not add up to total due to rounding.

Table 5 Chosen Key Performance Indicators (KPI's) for the two Quality Domains - Research Quality and Relevance to Society - for the four ME Departments

	RESEARCH QUALITY	RELEVANCE TO SOCIETY
Outcomes	**Research products for peers** 1. Research output: - Research articles - Books (+ book chapters - Dissertations 2. MSc/BSc theses that lead to publications 3. Senior researchers from abroad for fellowship (> 3 months)	**Research products for societal target groups** 1. Academically qualified engineers 2. Outreach activities, e.g. lectures for general audience, appearance in media (television, radio, newspapers, social media, exhibitions, events e.g. Dutch design week, Articles in professional journals) 3. Prototypes, products 4. Spin-offs/start-ups - spin-offs that cooperate with the UT - spin-offs that are taken over by a large industrial venture
Use of outcomes	**Use of research products by peers** 1. Use of products (e.g. datasets, software) by peers 2. Reviews in journals / Citations 3. Use of research facilities by peers	**Use of research products by societal groups** 1. Patents/licenses 2. Projects that are (partly) financed by industry / societal partners, staff working in industry 3. Use of research facilities and products by industry / societal partners
Recognition	**Marks of recognition from peers** 1. Science awards/prizes 2. Personal research grants 3. Membership of scientific committees, editorial boards, etc.	**Marks of recognition by societal groups** 1. Public or Industrial prizes 2. Membership of advisory bodies 3. Temporary exchange / part-time positions / positions paid by industry/public sector

Table 6 Research output at level of the 4 departments of MIDE within the Faculty of ET

SEP OUTPUT TYPE	2013	2014	2015	2016	2017	2018
Refereed articles	206	242	232	236	220	238
Non-refereed articles	8	10	9	11	9	6
Books	6	0	1	1	2	0
Book chapters	18	8	22	6	29	6
PhD theses	33	32	31	33	24	28
Conference papers	196	155	173	198	154	209
Professional publications	22	19	10	8	10	17
Publications aimed at the general public	5	7	4	1	2	1
Other research output*	89	80	84	70	78	72
Total	583	553	566	564	528	577

*Inaugural lectures, abstracts, posters, etc.

Table 10 Indicators showing the societal relevance of the research carried out by MIDE

TOTAL MIDE	2013	2014	2015	2016	2017	2018
Outreach activities: • Lectures for general audience, exhibitions, events • Articles in professional journals	44 18	31 15	20 9	78 5	25 9	20 18
Professional publications	14	14	9	3	9	14
Patent applications*	2	3	1	2	3	5
Spin-offs	0	5	2	0	2	0
PDEng theses	0	3	1	7	5	18
% contract research	49	42	37	37	35	35

* researchers of MIDE are involved in these patents. Patents which are filed by contract research parties, based on research carried out with MIDE are not included, as the UT does not have a register for these patents.

Table 11 PhD candidates

MIDE	GENDER		N	SUCCESS RATE											
START YEAR	M	F	M+F	≤4 YEARS		≤ 5 YEARS		≤6 YEARS		≤7 YEARS		NOT YET FINISHED		DISCONT.	
				n	%	n	%	N	%	n	%	N	%	N	%
2008	17	5	22	2	9	10	45	16	73	18	82	2	9	2	9
2009	39	10	49	5	10	29	59	34	69	38	78	3	6	8	16
2010	18	5	23	3	13	9	39	14	61	14	61	0	0	9	39
2011	30	7	37	6	16	22	59	26	70	27	73	1	3	9	24
2012	24	6	30	3	10	14	47	18	60	20	67	6	20	4	13
2013	23	8	31	3	10	14	45	15	48	-	-	7	23	9	29
2014	29	5	34	3	9	13	38	-	-	-	-	19	56	2	6
2015	36	14	50	9	18	-	-	-	-	-	-	35	70	6	12
Sum	**216**	**60**	**276**	**34**	**12**							**73**	**26**	**49**	**18**

Note 1 All PhD candidates conducting research with the primary aim/obligation of graduating, based on a 0.8-1.0 FTE contract. This includes PhD candidates with employee status and contract PhD candidates without employee status, receiving external funding or a university scholarship, who are conducting research under the authority of the research unit with the primary aim of graduating.

Table 12 PDEng candidates

MIDE	GENDER		N	SUCCESS RATE											
STARTING YEAR	M	F	M+F	≤2 YEARS		≤2.5 YEARS		≤3 YEARS		>3 YEARS		NOT YET FINISHED		DISCONT.	
				n	%	n	%	N	%	n	%	n	%	N	%
2013	1	1	2			1	50	1	100						
2014	5	2	7	4	57	2	85					1	15		
2015	4	2	6	3	50	2	83	1	100						
2016	18	2	20	9	45	8	85			1	5			2	10
2017	8	2	10	4	40	1	50					3	30	2	20
2018	15	3	18	3	17	1	23					13	72	1	6
Total	**51**	**12**	**63**	**23**		**15**		**2**		**1**		**17**	**27**	**5**	**8**

Table 13 PhD and PDEng theses

TOTAL MIDE	2014	2015	2016	2017	2018	2019
PhD Theses	32	31	33	24	28	36
PDEng Theses	3	1	7	5	18	7