



Midterm report Civil Engineering 2017-2020

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1. Introduction

1.1 Introduction to TU delft

TU Delft was founded in 1842 as the Royal Academy for the education of civil engineers and has grown into a university with eight faculties, more than 26,400 students and 3,600 scientific staff members. TU Delft's vision is: "Delft University of Technology contributes to solving global challenges by educating new generations of socially responsible engineers and expanding the frontiers of the engineering science".

This led to the following mission:

- We perform world-class research by combining science, engineering and design in a socially responsible manner. Thus, we advance and share the benefits of technology.
- We develop and enhance the expertise of tomorrow's engineering leaders and educate professional, high-level and responsible engineers throughout their careers.
- We help to develop and deliver technology-driven, innovative solutions to societal problems through collaborations with leading national and international partners whilst being firmly rooted in Delft.
- We continuously improve our collective effectiveness, performance and organisational resilience through the principles and practice of professionalism, collaboration and openness

To explain the nature of research carried out at TU Delft, we use a classification in two dimensions as shown in Figure 1.

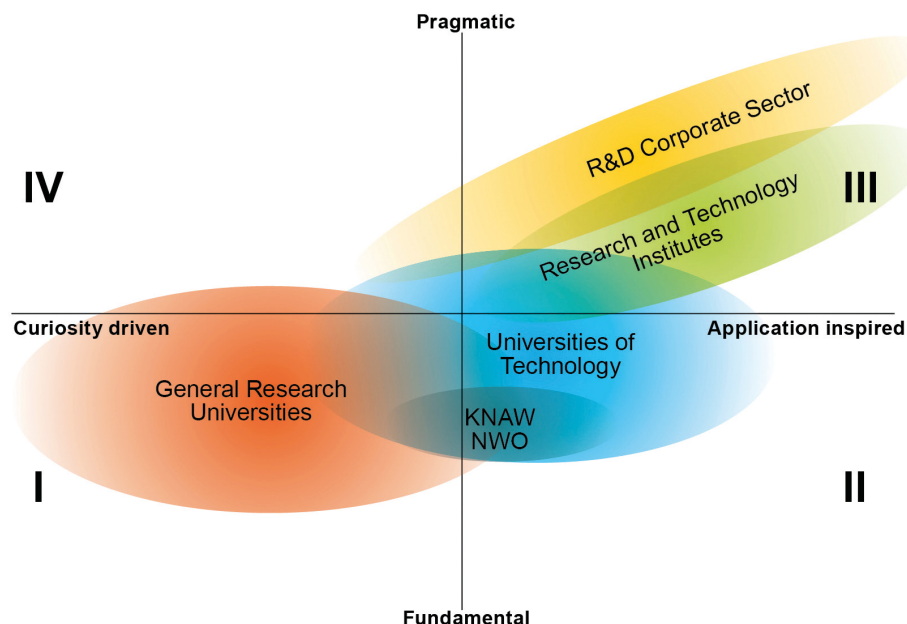


Figure 1: Two-dimensional field describing the nature of research (from TU Delft roadmap 2020).

The first dimension concerns the motivation of the research activities, which may range from curiosity-driven to application-inspired, as indicated on the horizontal axis. The second dimension concerns the nature of the research activities, which may range from fundamental to pragmatic as indicated on the vertical axis. Both general research universities and universities of technology are primarily concerned with fundamental

research. The difference between these two types of university lies in the motivation for their research, namely curiosity-driven or application-inspired. Universities of technology share the application-inspired motivation with large research and technology institutes (GTIs; like TNO, Deltares or KNMI) or R&D departments of the corporate sector. Their research differs, however, in the nature of the respective research activities. Whereas universities of technology such as TU Delft carry out (application-inspired) fundamental research, technological institutes and industry are mainly engaged in more pragmatic and short-term oriented research, aiming at solutions of challenges of today and tomorrow, where universities are aiming at challenges of the future. The common motivation to tackle societal and technological needs, inspired by applications, forms the basis for our cooperation with industry. The difference in the nature of research is reflected in the structure of many of our collaborative research contracts. Fundamental research questions are addressed in PhD and postdoc research projects, whereas the more pragmatic research questions and the implementation aspects are addressed by research staff from our partners at GTIs or industry.

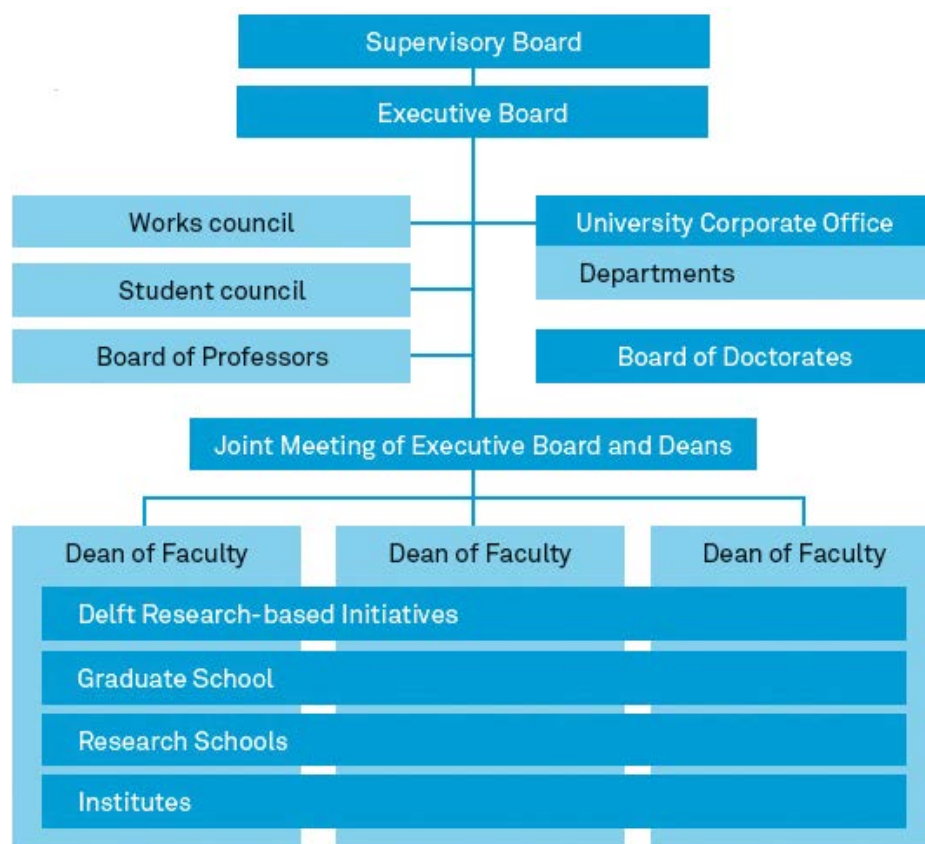


Figure 2: Main organisation of Delft University of Technology

TU Delft consists of eight discipline-oriented faculties, while interdisciplinary activities can be developed on a broader scale either in interfaculty research institutes, in university-wide research- based initiatives (DRIs) or in (inter)national programmes (Fig. 2).

1.2 Introduction to the faculty of Civil Engineering and Geosciences

In short, the mission is to create a better living environment for society.

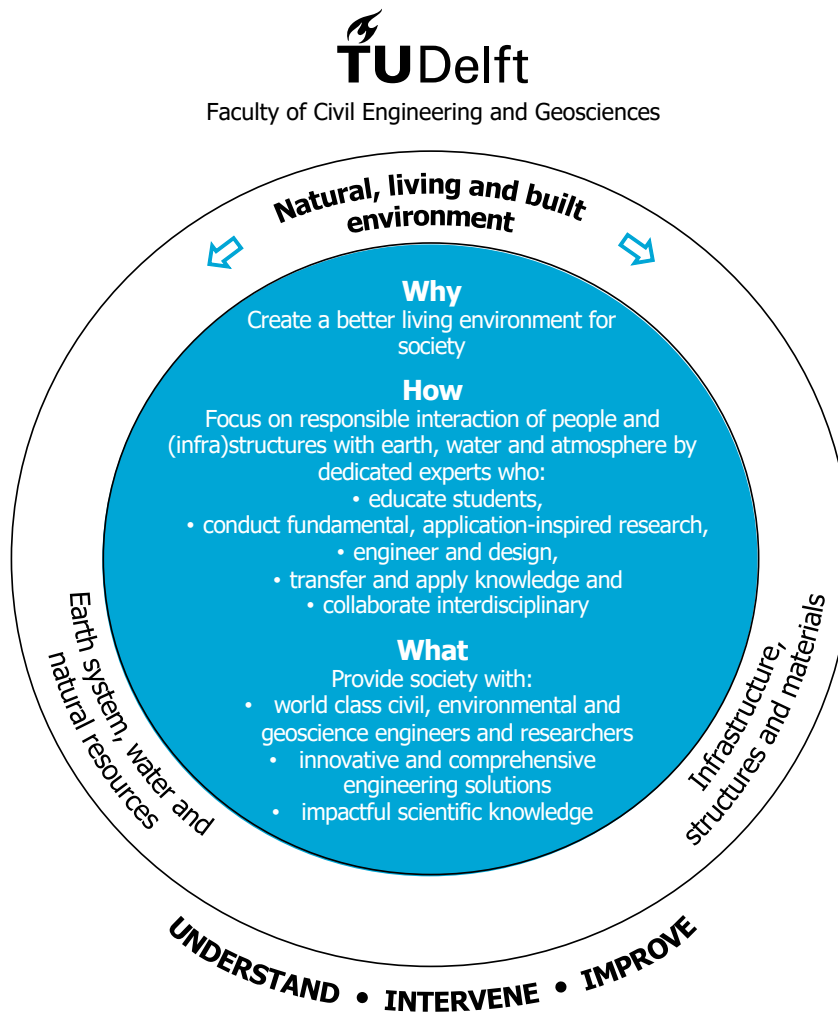


Figure 3: CEG strategy 2019-2024

In figure 3, vision, mission and strategy are represented in a nutshell.

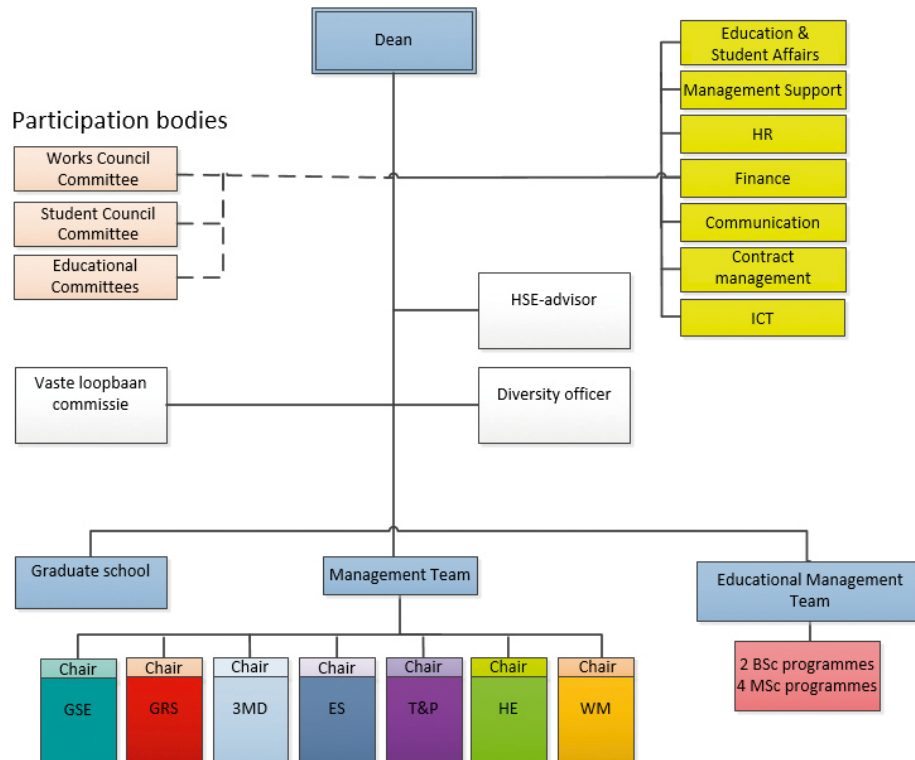
Contributions by the Faculty in research are recognised worldwide: in the recent Shanghai disciplinary ranking, TU Delft is number six in in Transport Science & Technology , and nine in Water Resources for an important part due to results obtained at CEG. In 2021 Engineering – civil and Structural TU Delft is at place 3 in the QS World University Ranking by subject.

Prof.dr.ir. Jan Dirk Jansen is since May 1st 2018 , the dean of the Faculty of Civil Engineering and Geosciences. He is overall responsible for research, education, valorisation and management. The Faculty consists of seven programmes in the form of departments: two in geoscience (reviewed two years ago) and five in civil engineering, being:

- Engineering Structures (ES);
- Hydraulic Engineering (HE);
- Transport & Planning (TP);
- Water Management (WM);
- Materials, Mechanics, Management & Design (3MD).

The dean, the seven department chairs and the director of education form the management team (MT) responsible for the strategic decisions about research directions and major developments in educational and valorisation processes.

The Faculty Secretary and the managers HR and Finance also participate in the MT meetings to guarantee a direct link to the execution of the decisions. The Faculty regulations describe the governance and operations of the Faculty.



Organogram 1

The director of Education and the four directors of study form the educational management team and are responsible for all educational matters for the studies Civil Engineering (CE), Transport, Infrastructure & Logistics (TIL), Construction Management & Engineering (CME) and Applied Earth Sciences (AES).

The support staff exists of 8 departments: Education & Student Affairs, Management Support, Human Resources, Finance, Communications, Contract management and Information Communication & Technologies.

Participation of employees and students is organised through a chosen Work council (employees) and the Faculty Student Council. Periodically the councils separately meet with the dean on policy matters.

The Faculty also as a director Graduate school (see chapter 3) and a Diversity officer. The diversity officer has a broad role to serve as an ambassador for D&I, initiate faculty activities to increase the awareness of students and staff on diversity and inclusion topics, assists in implementing the policy and promote D&I competency training for faculty staff and students.

The Faculty is supported by an HSE-advisor.

Facilities to support research at the Faculty comprise extensive and unique laboratory infrastructure, enabling CEG to perform experimental research in a wide range of scales and on a wide scale of topics (from large scale mechanical testing to research

on biohazardous sludges), computers and datacentres for modelling & simulation to equipment like drones, jet skis and cars for field measurements. The Faculty also executes experiments in real-life settings. The facilities are mostly in-house labs and in many cases unique installations. Examples of large field experiments are the mud engine (IJsselmeer), the sand engine (North Sea), and research in Estuaries (Zeeland, Wadden), along rivers, monitoring traffic flow or the behaviour of infrastructure. In this review period, the shift towards virtual and real-life settings has accelerated further, although (field)labs continue to be essential to validate numerical simulations. Examples of participation in living labs are the Amsterdam-based Advanced Metropolitan Solutions centre and the field labs of the Valorisation Programme Delta.

1.3 Relevant developments

1.3.1 External

Sustainable development goals

In 2015 the United Nations formulated the 2030 Agenda for sustainable development which was an urgent call for action on the formulated 17 Sustainable Development Goals (SDGs). A large part of the SDGs can be connected to our own mission to create a better living environment for society. The SDGs are becoming more and more part of global partnership between developed and developing countries, inter-/national policies and of criteria set by funding agencies.

The SDG's have been of great value to give direction to the Faculty in defining its research strategy. The Faculty hosts the TU Delft Global Initiative which motto clearly addresses its obligation to the SDG's: "Science for the benefit of people. All people. Worldwide."

Artificial Intelligence (AI)

The impact of AI, Data and Digitalisation technology can be felt in almost all aspects of science and society. This is further exemplified by the fact that it is prominently present on every agenda, both nationally and internationally. TU Delft recognized this important development, and in order to retain and strengthen its position as a world-renowned University of Technology, it started a programme to include state-of-the-art AI, Data and Digitalisation in its core activities research, education and valorisation. Over the course of 2020-2021 the TU Delft established a total of 16 TU Delft AI-labs where experts in AI *foundations* work together with experts in AI *challenges*. Through these Delft AI-labs, expertise and innovation in AI, Data & Digitalisation is used to advance expertise and innovation with AI, Data & Digitalisation, thereby increasing the impact of AI at TU Delft in science, design engineering and society. The coming period another 8 AI-labs will be established at the TU Delft.

Currently the Faculty participates in three DAI-labs; AIDRO (AI for sustainable water management), SLIMMlab (statistical learning for intelligent Material modelling) and CityAI (A place where data, AI and behavioural theory come together) and hired 2 new TT and 6 PhD's within this programme.

Governmental investments

Sector Plan

In 2019 the Dutch government made 60 million euros available annually for strengthening academic university research in technical and natural sciences. With these so called Sector Plans, the Ministry of Education, Culture and Sciences strives to reinforce the foundation of the natural and technical sciences, by attracting new research talent in order to expand research capacity. The Sector Plan also contributes to overarching goals such as more strategic cooperation between universities, increasing diversity and strengthening education, research and valorisation.

One of the technical sciences is Civil Engineering and a yearly budget of 1,75M euro is granted to finance 12 tenure track positions in 7 focal areas:

- Fluid dynamics and sediment transport in human-influenced marine, inland and urban water systems
- Fluid structure interactions for infrastructure and for nature based solutions
- Materials and environment
- Computational mechanics of materials
- Dynamics and monitoring of structures and infrastructural components
- Interface and multi-scale mechanics of structures
- Soil mechanics

Van Rijn – report

On request of the ministry of Education, Culture and Sciences the committee-van Rijn reviewed the funding of education and concluded that higher education should become less dependent on student growth for funding and a larger part of the budget should be directed to science and technology education. TU Delft developed a program to distribute the funds within the University. The CEG Faculty is allocated annually 1.2Meuro to raise the number of teaching staff and to strengthen the educational support. Six of these positions are Tenure track assistant professors and also have a research profile.

Covid-19

The worldwide Covid-19 pandemic started end 2019 and led to a lockdown in the Netherlands since March 11th 2020. As of this date, the default was to work from home, which was strictly applied by TU Delft. Only in exceptional cases (experimental work, educational tasks which could not be carried out at home and in case of mental/physical problems), following strict rules, scheduled working at CEG was possible. In general offices were closed, experiments minimized and education was shifted to online. Research kept its pace, when possible it was redirected to computer-based work and conferences and meetings also shifted to online. After more than a year we are proud of what has been achieved despite the difficult situation. As an example, the number of PhD-defences did not change, demonstrating that we managed to continue our research activities. However, we do feel the impact on our employees. These are mainly social effects, such as missing colleagues at work, not being able to visit family abroad, feelings of loneliness and being cut off from the regular academic environment.

1.3.2 Internal

Organisational structure and culture

Since the previous research assessment in 2018, the faculty continued to operate with seven departments, two mostly operating in the geosciences domain (not part of this review) and five in primarily the civil engineering domain. However we note that several departments perform research activities that cross the traditional geoscience/civil boundaries; e.g. the “geo departments” carry out some of the research in traditional civil engineering topics like soil mechanics and geodesy, while the “civil departments” perform some of the research in traditional earth sciences disciplines like hydrology and oceanography.

Over the past period we have experimented with various forms of organisational structure within the departments, with the aim to create more departmental coherence, a less hierarchical structure and room for increased participation of “younger” staff, in particular (tenure-track) assistant and associate professors. Generally speaking, the role of sections as nearly independent sub-units has been strongly reduced and, as a matter of policy, decisions about finance, strategy and staff (new hires) are taken primarily at department level. Two of the “civil departments” have actively experimented with a new organisational structure, notably Transport and Planning who introduced a Lab structure, and Engineering Structures, who introduced a “Young MT”. We aim to develop a set of

shared starting points and boundary conditions within which the departments can choose their organisational model, somewhere in between the traditional “pyramid” and a totally flat “PI model”, such that we increase the freedom of individual researchers to excel while maintaining a considerable degree of cooperation and teamwork.

Another step to increase the empowerment of our “younger” scientific staff has been the conscious decision to invite them to take the lead in the educational revision of our MSc programs. The initial project team, which designed the overall structure and main content (tracks and cross program modules) consisted mainly of (tenure track) assistant and associate professors. Thanks to their fresh view on the current and desired future contents of our educational program we have ended up with a significantly renewed curriculum (See Strategy process and result).

Tenure track system

Over the past decade we have gradually adopted a version of tenure track system where assistant professors are hired on a temporary contract. During a five year period they are expected to demonstrate their suitability for an academic career through developing an independent research line, acquiring funding to build their own group of PhDs and PostDocs, demonstrating and developing their teaching skills, publishing in high quality journals, performing as a team member, and growing organisational and leadership skills. If successful they obtain a permanent position as assistant professor with the expectation to be promoted to associate professor within a maximum of five years (but often much faster). An important recent change has been the introduction of the perspective of a subsequent internal performance-based promotion to full professor (governed at university level) which has replaced the traditional system of a limited fixed number of full professor “chairs”.

Clearly, this entire academic career development track is a very demanding and high-intensity process. Over the past years it has resulted in an influx of high quality staff with often rapid career development, but also in a high stress level and sometimes frustration amongst tenure trackers. Over the past two years we have therefore performed an extensive review of our tenure track system, including input from a larger representation of younger staff. This review resulted in several changes, notably more credit for team-based performance, more room for education as a primary focus rather than research, and a stronger coupling of the regular yearly results and development cycle to the agreements as documented in individual tenure track plans. Moreover, we have increased the level of financial support for starting tenure trackers who now all receive a start-up fund to directly hire a PhD student. Another change, pending agreement at university level, is a decoupling of permanent contract provision and assessing the suitability for an academic career.

Leadership, diversity and further elements of academic culture

Increasingly we pay attention to leadership development of our academic staff. In addition to initiatives at university level we developed an in-house leadership course for (mainly) associate professors, and provided many staff with opportunities to attend external leadership programmes or obtain coaching-on-the-job. The yearly results and development cycle includes preview and review meetings for each department attended by the departmental MT, the HR manager and departmental HR advisor, the director of education and the dean, during which individual staff development is discussed in terms of research, education, valorization, organisation and leadership.

Another important point of attention has been the attraction of female staff. We participated in the university-wide Delft Technology Fellowship. Moreover, we decided at Faculty MT level to aim for at least 50% female candidates for all Sector Plan and van Rijn positions (see above). We therefore actively stimulated vacancy holders to scout for female talent, and employed the services of a dedicated agency (Web Shark), resulting in 11 female and 11 male new-hired (tenure-track) assistant and associate professors. Nevertheless, we realize that we still have a long way to go before the gender balance in our staff is at least

on par with the gender ratio in our student population (about 30% female), especially in senior (full professor) and faculty MT positions.

Another aspect of diversity concerns the ratio of “home grown” versus “external” staff. Out of the 22 newly hired Sector Plan and Van Rijn professors, six were formerly associated to TU Delft (as MSc student, PhD or PostDoc) while the other 16 originated from universities world-wide. We much value the benefits of a diverse academic community, and we welcome an international staff influx. Unavoidably such an increasing diversity in cultures and nationalities also leads to an increasing variety in expectations, values and beliefs, sometimes resulting in disappointments, conflicts or undesirable behaviour. No doubt, the Covid measures of the past 1-1/2 years, which virtually ended all face-to-face personal contacts, have worsened some of these problems. As one of the measures to develop and reap the benefits of a diverse community, and overcome the negative side effects, we recently appointed a Faculty Diversity Officer, who will work closely with the TU Delft Diversity Officer. Furthermore, two years ago our PhD community organised themselves in a representative PhD council, which now also has a formal representation in the OdC (works council). However, a better representation of our PostDoc community is still outstanding. Also, as a preparation to this mid-term Research Assessment, we requested an ad-hoc Academic Culture committee, chaired by a Assistant Professor, to reflect on how they experienced the academic culture in our faculty. An overview of their findings has been included in the report as chapter 4. It clearly shows that, although we addressed many aspects of academic culture over the past period, there is still considerable room for improvement, at a policy level as well as in communication and implementation at all levels of the organisation.

1.4 Assessment on Faculty level

1.4.1 Review recommendations

This section describes how we have addressed the recommendations from the previous research review.

Computing facilities

The faculty played an active role in the realization of the TU Delft High Performance Cluster (DHPC). This is a heterogeneous computing cluster for the whole university, consisting of the newest computing and data nodes (partner Fujitsu, approx. 30.000 cores, operational in November 2021). The machine will facilitate scientific breakthroughs in large-scale, complex civil engineering problems, for example in the fields of environmental flows, reservoir simulation, multi-modal transport and multi-scale material mechanics. The DHPC will also be used for the training of our BSc-, MSc- and PhD-students by means of advanced courses on massive parallel computing.

Web presence

The faculty has taken up the task to work on a more uniform way of representing its departments and departmental staff. Staff members can more easily be localized on the website through the staff item in the top menu-bar on the website, which is now identical for all departments. The department of hydraulic engineering has chosen to represent its staff members on section level. Most departments represent their staff in academic categories and identical personal pages. The profiling of staff members has been improved by adding specific stories of science about their research to their personal pages, as well as their media exposure (where and if applicable).

Funding

Over the years the total funding of the Faculty remained stable. The positive effects on the Direct funding due to the Sector plan and Van Rijn report are not yet visible in the numbers. From 2021 we will see the raise of the Direct funding with approximately 15%. We expected that research grants and contract research will equally raise over time. New personnel will also apply for funding from these sources.

Research is financed primarily via the funding agencies within the Netherlands (Research grants) and the European Union (H2020) which is part of Contract Research. A considerable part of our PhD-research is executed by bursary PhD candidates and is not visible as such in the funding table.

Until recently no Direct funding was available for PhD or PostDoc research. However, the recent hiring of 22 new research staff members in 2020 (most of which are in tenure track positions) with another expected 20 staff in 2021, and the availability of additional funds from the Sector Plan and van Rijn schemes allowed us to review this policy and we now provide all new assistant professors with a directly funded PhD student and new associate professors with a 200 k€ start-up package.

The Faculty is in an healthy financial state. Additional investments in personnel and infrastructure are being discussed.

Table 1

2017			2018		2019		2020	
ALL CE departments								
Funding:								
Direct funding (1)	20.306.702	50%	18.162.055	44%	19.311.005	43%	19.935.010	46%
Research grants (2)	6.760.654	16%	7.760.175	19%	8.046.117	18%	7.239.929	17%
Contract research (3)	12.708.551	31%	14.005.657	34%	15.958.163	36%	14.460.295	33%
Other (4)	1.218.967	3%	1.558.788	4%	1.299.258	3%	1.856.840	4%
Total funding	40.994.875	100%	41.486.675	100%	44.614.543	100%	43.492.074	100%
Expenditure:								
Personnel costs	-32.303.562	79%	-35.780.065	86%	-37.975.594	84%	-36.876.356	88%
Other costs	-8.382.875	21%	-5.758.974	14%	-7.319.364	16%	-5.149.834	12%
Total Expenditure	-40.686.437	100%	-41.539.039	100%	-45.294.959	100%	-42.026.190	100%

Note 1: Direct funding (basisfinanciering / lump-sum budget)

Note 2: Research grants obtained in national scientific competition (e.g. grants from NWO and KNAW)

Note 3: Research contracts for specific research projects obtained from external organisations, such as industry, government ministries, European organisations and charitable organisations

Note 4: Funds that do not fit into the other categories

Sharpen Strategic and integral thinking on societal impact

See paragraph Strategy process and results

Connections to universities of applied science

The relationship between the TU Delft and the universities of applied science was in the past mainly defined by graduates of the universities of applied science starting their MSc-education, or cooperation agreements on institutional level. Funding agencies created research programmes especially for universities of applied science, which offer possibilities to cooperate. Currently the bottom up approach is most effective. Scientists start projects based on content and their complimentary qualities.

More and more attention is focused in the Sectorplan to strengthen this relation.

The upcoming period the Faculty will have to broaden and strengthen the cooperation with the Universities of Applied Science.

1.4.2 Strategy process and result

The departments of the faculty all have proven to be successful at education and research in their own disciplines, resulting in the faculty's strong position. However, to make impact in a world that is highly subject to change, the faculty has to find a balance between responding to current and future developments in society, and maintaining the strengths of its core disciplines.

In 2018 the Management Team of CEG decided to review and update the Faculty Strategy to define where the faculty should be in 2023. The purpose of this strategy is to enable and guide all departments and their personnel in necessary decisions regarding research priorities, educational program and budget within the overall TU Delft Strategic Framework. It should provide shared boundary conditions for the organization and provide a basis for next Civil Engineering and Geo Sciences research evaluation cycles.

We emphasized that the process towards the faculty strategy should be as important as the result itself and therefore be designed as a bottom-up process. To make sure the defined strategy truly reflects the shared vision and goals of (especially younger) academic staff, we ensured their participation in the project team which consisted, by design, mostly of (tenure track) assistant and recently promoted associate professors. The project team delivered and communicated the strategy document, liaised with the departments and managed dependencies. Senior research staff was involved on a voluntary basis in the strategy development process by participating in so-called walk-in sessions. Furthermore, junior research staff (including post-docs and PhD candidates), support staff and student council have participated through a review process. Decisions were made by the faculty's management team. Taken together, the approach towards the strategy was a real combination of bottom-up and top-down. The strategy development process started with collecting the most important societal challenges, most relevant emerging technologies and most needed core disciplines per department. After intensive assessment and dialogue, the project team formulated the faculty's why, how and what (figure 3) as a proposal to their colleagues. In the following iterative process this intermediate result was sharpened, and ultimately adopted by the majority. In the same manner, strategic ambitions were formulated by the project team on the key activities 'student and education', 'research and innovation', 'people and community' and 'campus and services'. Next, change themes and strategic choices were defined considering the faculty's ambitions and its current position.

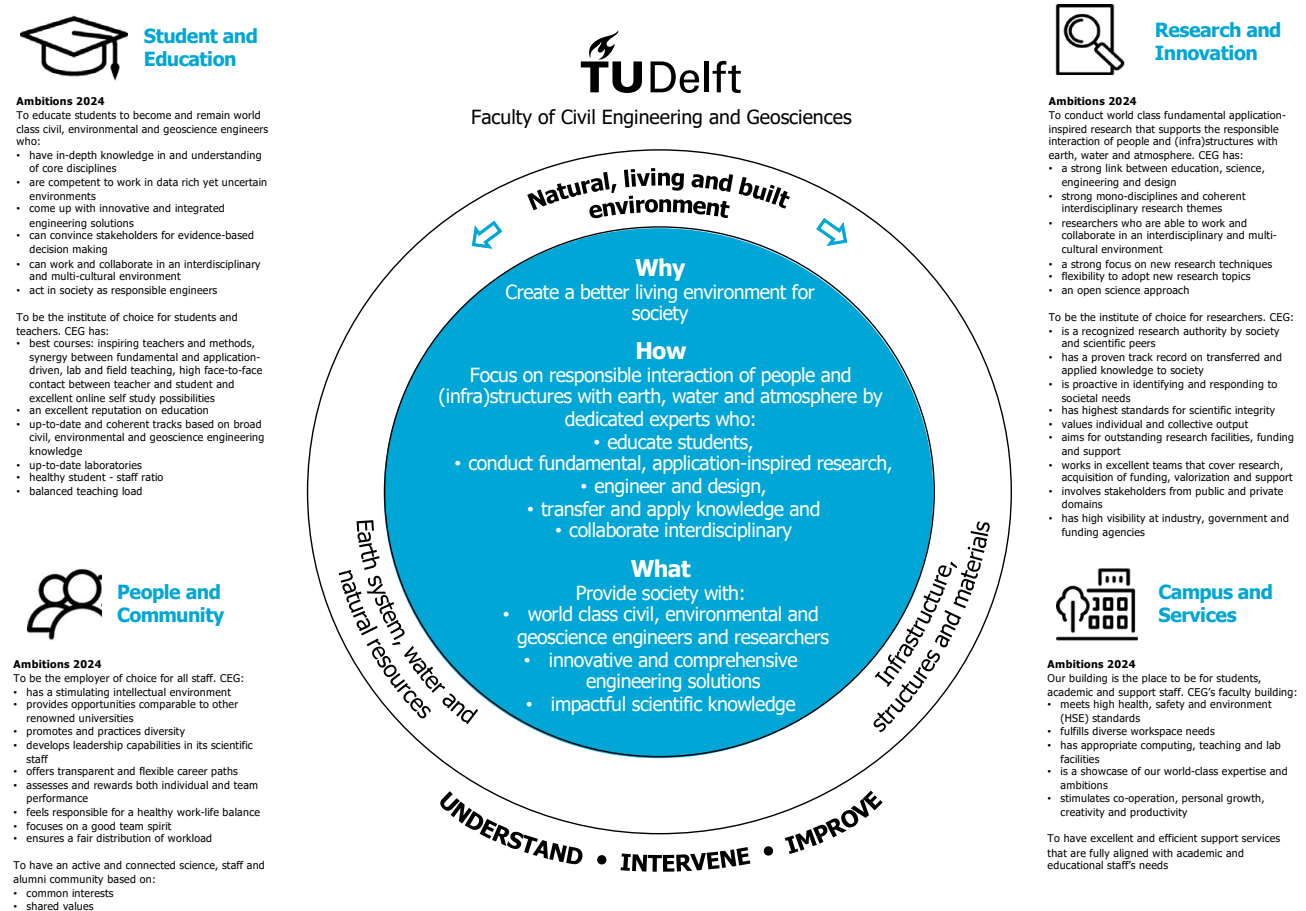
All (intermediate) results were broadly communicated within the faculty.

In order to keep it practical for everyone the faculty's strategy came as a (double-sided) one pager.

In order to have a controlled implementation the strategic choices were prioritized. Triggered by the results of two educational reviews of the Applied Earth Sciences and Civil Engineering BSc and MSc programs, the faculty has started with the redesign of the educational programmes as the major element of the strategy implementation process. As of September 2022 CEG will offer 3 master's programmes: the *revised* master's programmes Applied Earth Sciences (AES) and Civil Engineering (CE) and a *new* master's programme called Environmental Engineering (ENV). This will create a balanced and future-proof range of education within the faculty that meets the needs of (potential) students, the questions that future employers pose to our alumni and the professional requirements we set for ourselves.

The master's programmes are in line with the major and complex challenges facing our society, such as climate change, energy transition and the transition to a more circular society combined with our ongoing focus on important challenges such as resilient infrastructure to ensure safety against natural hazards and reliable transportation networks and understanding system earth and its climate system.

Figure 4: CEG Strategy Onepager 2019-2024



Student and Education

Change themes 2019-2024	Strategic choices 2019-2024
Curriculum structure and content	<ol style="list-style-type: none"> 1. Give core disciplines a structural place throughout broad BSc programs as a basis for advanced specialization in the various master programs 2. Challenge the status quo of existing BSc and MSc programs and tracks and decide on and implement necessary improvements in line with CEG mission statement 3. Give emerging technologies and societal challenges a recognizable role in both BSc and MSc programs 4. Oblige interdisciplinary education in MSc linked to the key societal challenges for CEG
Environment for education to grow	<ol style="list-style-type: none"> 1. Enhance skill-based knowledge like academic writing, presentation and programming 2. Improve educational facilities (i.e. instruction rooms, e-learning facilities, computing) and educator support 3. Create extra-curricular showcase projects for students to participate in (CEG dream teams)
Distribution of teaching load	<ol style="list-style-type: none"> 1. Distribute teaching load more evenly over departments and individuals 2. Increase the number of lecturers per BSc course with specific in-depth knowledge on course aspects involved 3. Distribute student influx more evenly over the MSc-tracks
Education and promotion culture and efficiency	<ol style="list-style-type: none"> 1. 80% of students who have passed their BSA finish their BSc within 4 years 2. 90% of PhD candidates who have passed their go/no-go obtain their degree within 5 years.

People and Community

Change themes 2019-2024	Strategic choices 2019-2024
Appreciation of group and individual	<ol style="list-style-type: none"> 1. Appreciate in R&O and VLC also individual contributions to: <ol style="list-style-type: none"> a. the group output and responsibilities b. establishment and maintenance of external relations for education, research and valorisation c. societal impact and outreach 2. Change VLC norms to be tailored to individual talents: Faculty members should be excellent on at least one criterion and competitive on other criteria 3. Align R&O with VLC expectations and recommendations
Environment for individuals to grow	<ol style="list-style-type: none"> 1. Develop staff actively and based on transparent HR policy on recruitment, guidance, training, promotion and outplacement 2. Reward initiatives and responsibilities taken by individuals to get the best out of themselves and out of others 3. Integrate every Faculty members' actual personal mission statement and personal development plan in R&O cycle 4. Initiate a VLC track for the career development of lecturers
Inclusiveness	<ol style="list-style-type: none"> 1. Increase the number of female Faculty members (UD, UHD, HL) and lecturers to be a representation of the PhD population 2. Represent at least 1 junior staff i.e. 'young' U(H)D in each department MT 3. Apply zero tolerance on prejudices, gossiping and intimidation

Research and Innovation

Change themes 2019-2024	Strategic choices 2019-2024
Societal challenges and faculty research themes	<ol style="list-style-type: none"> 1. Align, focus and strengthen all research activities (including moonshots) concerning the key societal challenges for CEG: <ol style="list-style-type: none"> a. Availability of clean water b. Climate change c. Transition to renewable energy systems d. Resource depletion e. Urbanization 2. Set the societal agenda through mapping and involving of stakeholders aimed on the key societal challenges for CEG
Environment for research to grow	<ol style="list-style-type: none"> 1. Maintain strengths in following disciplines: <ol style="list-style-type: none"> a. Fluid and sediment dynamics b. Physics of materials c. Earth sciences d. Mechanics of solids and structures e. Transport network and system sciences 2. Develop cross-department methods and technologies: <ol style="list-style-type: none"> a. Monitoring, sensing and data b. Numerical modelling, simulation and design c. Risk analysis, uncertainty quantification, probabilistic design d. Smart materials and structures 3. Realize integrated use of experimental lab facilities of the faculty

Campus and Services

Change themes 2019-2024	Strategic choices 2019-2024
Health, safety and environment (HSE)	<ol style="list-style-type: none"> 1. Create an environment to have zero incidents: <ol style="list-style-type: none"> a. Staff at all levels take own responsibility in behaviour b. Clear organization, policy and procedures c. Implement structural HSE measures d. Have 100% coverage of safety reports for experiments e. Use dedicated HSE software routinely for registration and monitoring f. Publish safety performance
Co-ownership	<ol style="list-style-type: none"> 1. Ensure sufficient (quantity and quality) project and financial support staff to departments 2. Make distribution of responsibilities between academic staff and support staff fully clear and complied with 3. Make the degree of academic and educational staff's satisfaction a criterion in support staff's R&O and vice-versa
Building and workspace	<ol style="list-style-type: none"> 1. Aim for mid-term renovation with attention for: <ol style="list-style-type: none"> a. Improved spatial lay-out including more small meeting rooms b. Up-to-date interior design c. Improved climate control 2. Practice sustainability throughout the building including the restaurant

The redesign started with an educational framework that was approved by the faculty management team. The curricula of the programmes are all set-up around modules, which are thematically coherent educational entities. Each curriculum will in any case contain:

- Modelling, Uncertainty and Data for Engineers (MUDE): a joint faculty-wide teaching module for all three master's programs with learning lines in the field of modelling, data and uncertainty quantification;
- Programme Core: master-specific teaching modules that every student takes prior to the various tracks within the master's program;
- Space for a multidisciplinary project, cross-over programme modules and electives.

In particular the CE and AES MSc programmes will become more coherent and with more and better focus on intended learning objectives, thus providing a better instrument to manage future programme changes and innovations. We will emphasize on fundamentals and significant multi-disciplinary programme elements. Furthermore, we will incorporate a clear vision on personal, interpersonal and professional skills. Our future engineers must be educated to prepare them for changes in roles and careers

Another important aim of the redesign of the master programmes is to create a better balance in educational load between our colleagues in order to mitigate the risk to loosen staff through burn-out in systematically overloaded groups. Therefore, the teaching will be team-based and a mechanism to ensure a structural balanced teaching workload will be implemented. The redesign project is still on schedule for the master programmes to start in September 2022. Modules are being detailed, the macro efficiency test for ENV is in process, admission and transition plans are made, teaching teams are formed and (team) trainings are organized.

1.5 Outlook

The main effort within the Faculty the upcoming years is the implementation of our faculty strategy. Most effort in this phase is put in the MSc redesign. We will keep focus on our strength in the defined disciplines and develop cross-departmental methods and technologies. As important as the goals on research are the three interconnected other change themes: Student and Education, People and Community and Campus and Services. Alignment in their development directly influences the possible outcome.

In a broader scope we compete with other universities all over the world on scale, funding, personnel, etc.. In rankings, universities from Asia are taking over the top 10. With many of them we already have good relations and we will foster our complementary role. Creating cooperation on research itself gives opportunities to combine strength instead of competition.



2. Open Science

2.1 TU Delft Open Science Programme

Open Science is creating new forms of scientific interaction that were impossible or undreamed of in an earlier age. Therefore, Open Science has a strong impact on core academic processes like research, education and innovation. It is easier to replicate an experiment if publications, relevant data sets and software are digitally available. It is TU Delft's ambition to be frontrunner in this revolutionary Open Science process. This is reflected in the TU Delft Strategic Framework 2018-2024, with "openness" as one of its major principles with its Open Science Programme 2020-2024: Research and Education in the Open Era.

The TU Delft Open Science Programme 2020-2024 tackles all areas of scholarly engagement where restrictions limit the flow of academic knowledge. It proposes new approaches to the processes of research, education and innovation, with a strong focus on transparency, integrity and efficiency. The programme, updated in 2021, consists of seven interrelated projects, of which two were added as exploratory subjects after the evaluation of the 2020 workplan.



Figure 5

The projects are aimed at creating and disseminating various types of resources for the benefit of TU Delft researchers, teachers and students, as well as the general public. They will range from educational materials and software to a publishing platform. All outputs of the programme will be as "FAIR" as possible: findable, accessible, interoperable and reusable. The support from TU Delft is provided by faculty data stewards¹, 4TU datacentre¹ and the Digital Competence centre.

2.2 General

2.2.1 Ambition and aims

In a cycle of work plans, the ambitions within the TU Delft Open Science programme are translated into faculty aims. The faculty aims are focused on research output. However, in the current programme, strategies to reach the faculty aims are also taken into account, such as support services to optimise workflows for the interrelated projects and cross-cutting subjects. For this reason, the main focus for the faculty is further integration of the Open Science projects and cross cutting subjects within current and prospective research

cycles and work flows. The current integration of the Open Science projects is in place with regard to open access (OA), FAIR data and FAIR software, and it illustrates our steps towards the transition to the Open Era. Further integration requires the more conscious effort of researchers on the publication choice of journals (e.g., OA or non-OA), explicit data management plans (e.g., FAIR and/or open or closed datasets) and software choices (e.g., open or protected software).

2.2.2 Exploratory projects

Although there is no policy on citizen science and open hardware yet, there are departments who took initiative to develop low-key projects on these exploratory subjects. There are several ways in which citizens can participate in citizen science projects and the most common way is the participation of citizens in collecting data for research projects. For example, between July and September 2020, in total 95 citizens measured with a rain gauge the amount of rain in the project 'Delft meet regen'¹. Citizens received a manual and rain gauge kit that allowed citizens to make their own hardware, namely the rain gauge. These results were analysed by a TU Delft student (Illias Timori) whose supervisor was a TU Delft Researcher (Marie-Claire ten Veldhuis). They acknowledged that the daily rain gauge measurements were reliable and measured rainfall amounts comparable to those measured by a KNMI (the Royal Netherlands Meteorological Institute) close by. The advantage of the citizen rain gauge network is the much higher density compared to KNMI rain gauges. These results were displayed on an infographic and on a geographical map for citizens to see processing of their data. Another element which is connected to citizen science is how to involve citizens or societal groups in the definition of the research agenda. An interesting example on governmental level of this involvement is the process to define the Dutch Research Agenda (NWA)¹ in which a broad spectrum of stakeholders were asked to share their questions on the future. These questions were grouped and prioritised and formed the agenda.

Maturity

The elements of the TU Delft Open Science programme differ in maturity depending on the existence of a policy, integration in the research cycle, availability of support and management information (see Table 1). Two elements of the programme (open education and the open publishing platform) are not within scope of the Midterm CE—open education due to the focus on the educational process, and the open publishing platform due to the ownership of this element of the TU Delft library.

Table 2 – An overview of policies, the extent of integration, support and management information within the TU Delft and CE departments of the CEG faculty

	TU Delft	CEG faculty: CE departments		
	Policy in place?	Extent of Integration	Support	Management information
Open Access	Policy on Open Access Publishing	Fully	Web tools, contract manager, FIC	Quarterly reports
FAIR Data	Research Data Policy Framework	Fully	Data steward, Digital Competence Centre, 4TU research data officers	Quarterly reports after registration of datasets
FAIR Software	Research Software Policy	To be started	Data steward, Digital Competence Centre, legal services	Quarterly reports after registration of software
Citizen Science	Exploratory subject			
Open Hardware	Exploratory subject			

Impact of Open Science on research quality, societal relevance and viability

TU Delft has chosen for an ambitious approach to make Open Science the default within the practice of research. Variation on impact of research quality, societal relevance and viability will depend on the extent of compliance in open practices across the faculty and does not depend on choices at department level. This faculty approach fosters the benefits of standardised support and unambiguous policy in each department and facilitates the intrinsic drive of scientists. This drive led to a broad support for the goals of the Open Science programme. The faculty staff experiences the advantages of a free flow of knowledge and transparency due to the availability of open publications and datasets. The advantages are particularly beneficial for groups outside the Dutch academia or in developing countries who initially only could have access to research output after paying for the knowledge. Open discussions on Open Science are held regarding the advantages, but disadvantages are also considered. For example, how do we deal with peers in developing countries who are not able to pay OA fees to the publisher in order to make their publications open? How can we facilitate their participation in the Open Science movement? In conclusion, the main effect of the Open Science movement will lead to higher credibility of research by higher transparency and reproducibility and on outreach due to the free flow of knowledge to a potential greater audience. These effects positively influence all three criteria in the assessment.

Stakeholder involvement

The government is setting conditions in funding schemes on the accessibility of the outcome. This greatly shaped the stakeholder involvement until now. Hardly any industrial party sets conditions on the FAIR accessibility of the outcome. More often, negotiations with those parties focuses on the disclosure of – mainly – research data. The TU Delft has set limitations on the period during which an embargo on the data is in force.

2.4 Open Access publications

2.4.1 Policy

Open Access publications are defined as a collection of peer-reviewed articles, letters, letters/comments to the editor, special issues and review articles. The current policy to publish 100% open access is the ambition. Yearly goals are set to realise this ambition. Since 1 May 2016, two developments have had a great influence on the current policy. First is the so-called Taverne amendment which legally grants authors, after signing the Taverne agreement, the right to openly publish their work after a reasonable period in the Netherlands. This embargo period is set to six months. So called short publications of an author can therefore become open access available. Second, in the framework of Plan S, the funding agencies of Europe and the Netherlands have as of 1 January 2021 demanded that all projects which are funded via their agencies should be direct open access. This is a more narrow definition than the original TU Delft Open Access policy.

2.4.2 Integration

In the different phases of research, open-access publishing is taken in account. In the application process funds for OA publishing are budgeted, the TU Delft Journal Browser can be used to select OA journals, and recently the Plan S Journal Checker Tool¹ has been introduced to inform researchers upfront on Plan S-compliant OA journals. After publication of the articles by the publisher, OA articles are “harvested” directly by the TU Delft library to be registered in Pure (the current research information system; CRIS) and published in the TU Delft research repository. If the publication is not directly OA available, the TU Delft library uploads the publication of the last author's version in the repository or the original article, with an embargo of six months if the researcher has opted for the Taverne amendment.

2.4.3 Support

The integration of OA publishing in this process has progressed to a level that the support on faculty level is integrated into the work of staff which has a role in the research cycle: contract managers on the funding side and faculty information coordinators on collecting and reporting data on OA. On the central level, the TU Delft library has designed tools to help researchers in selecting a suitable OA journals and workflows to register in Pure and archive journal articles in the TU Delft repository.

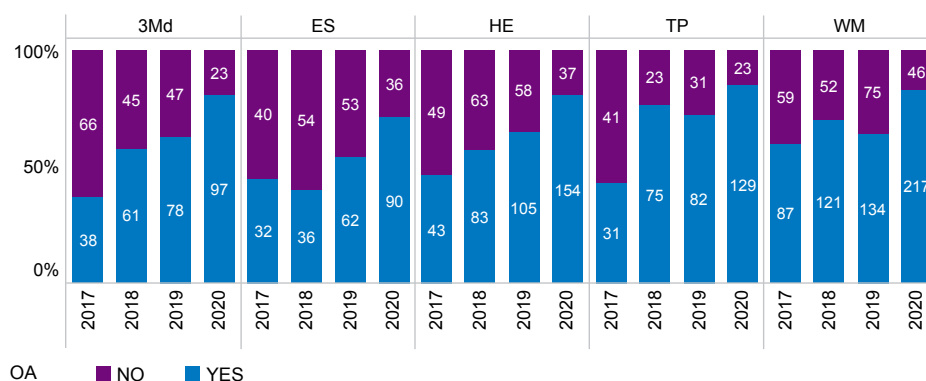
2.4.4 Management information

Within Pure, all publications are registered. This systems offers the possibility to report at the individual and organisational level. If an employee is reviewed on his/her performance, a list is compiled of the number of articles, and the percentage of OA is provided. The same is done on organisational level. The reports are used as “comply or explain”. Possible explanations for non-OA are found in older publications before the Open Era or by demands from a “semi-closed” association. In the latter case, activities have been undertaken to open up the association with the use of the Taverne Agreement or to shift publishing in an alternative journal.

2.4.5 Results

The official yearly progress of open access publications is measured by the TU Delft library in April the following year. In Figure 6, the progress of open access publications (represented in blue) in comparison with closed access (represented in grey) is illustrated for 2017, 2018, 2019, 2020.

% Open Acces | Document type: Journal | Source: TUD Library



% Potential Open Acces | Document type: Journal | Source: TUD Library

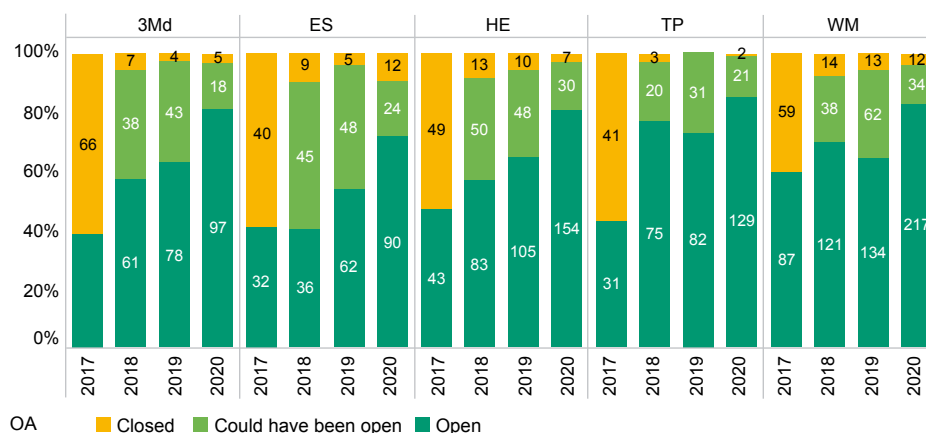


Figure 6 Progress in percentage and frequency of peer-reviewed open access publications of each CE department in 2017-2019. Source: Pure; Reference dates: In each year, the progress is measured in April in the following year (e.g., in April 2018, the progress was measured of 2017)

The dean has quarterly meetings with the department on operational processes, HR, finance and research, among others. The management information on open-access publications in Table 3 is also discussed in these meetings. This table gives insight in trends, but also the possibility to focus on the potential publications, which are non-OA, but could have been OA.

Table 3 Progress on open access availability of publications of each CE department in Q1 during 2020

Articles registered in Q1 2020 CEG

CEG - Open Access indication, during the year*									
Articles that are open or embargoed Q1 2020	Reference date 29-4-2020		Reference date 1-8-2020		Reference date 1-11-2020		Reference date 1-2-2021		Total articles registered in Quarter
3Md	37	79%	37	79%	37	79%	40	85%	47
ES	19	68%	20	71%	20	71%	20	69%	29
GRS	32	80%	35	88%	35	88%	38	95%	40
GSE	34	81%	36	82%	36	82%	36	80%	45
HE	40	75%	43	81%	44	83%	46	87%	53
TP	32	89%	34	89%	35	90%	35	90%	39
WM	56	82%	61	88%	61	88%	62	90%	69
CEG	250	80%	266	83%	268	84%	277	86%	322

CEG - Articles that could have been open, during the year									
Articles that could have been open Q1 2020	Reference date 29-4-2020		Reference date 1-8-2020		Reference date 1-11-2020		Reference date 1-2-2021		Total articles registered in Quarter
3Md	7	15%	7	15%	7	15%	4	9%	47
ES	6	21%	5	18%	5	18%	5	17%	29
GRS	6	15%	3	8%	3	8%	1	3%	40
GSE	5	12%	4	9%	4	9%	4	9%	45
HE	10	19%	7	13%	6	11%	4	8%	53
TP	3	8%	3	8%	3	8%	3	8%	39
WM	8	12%	4	6%	4	6%	3	4%	69
CEG	45	14%	33	10%	32	10%	24	7%	322

* This is an indication; The Library will calculate a definite percentage once the year has ended.

NB: The total number of articles is larger than the sum of open access articles and articles that could have been open, because there will always be articles that cannot be open access at all.

NB: the number of articles in a quarter can become higher or lower at a later point in time (and thus the percentage too) because an article can be (dis)approved in the mean time (only approved articles in Pure are taken into account).

2.5 FAIR data

2.5.1 Policy

The TU Delft developed a template which gave faculties two options to integrate data stewardship within the research cycle of CEG researchers. In the faculty data management policy of CEG, it is defined that the supervisor, principle investigator (PI) and line management have the task of facilitating training of researchers in data management. The research data should be archived in a FAIR way, meaning Findable, Accessible, Interoperable and Reusable. The default practice is open FAIR data on a “Comply or explain” basis.

2.5.2 Integration

In the different research phases, FAIR data is considered. In the application of a research proposal, the budgeting of funds for data management (e.g. a dedicated data manager for the project), storage and archiving is taken into account. The data steward guides researchers through the process of making a data management plan and acts as a liaison to 4TU.ResearchData and the Digital Competence Centre. Datasets are archived in a so-called sealed data repository (e.g. 4TU.ResearchData) and are made visible in Pure. Datasets can be directly linked via a DOI to the article in which it has been used. This offers readers of the article easy access to the underlying data for (re-)use of the data.

The starting point of FAIR data management is either via the training sessions the data steward gives to researchers or via a report of newly started projects which triggers the data stewards to reach out to the PI. Research with human subjects has to get ethical clearance from the Human Research Ethics Committee (HREC) which requires a data management plan approved by the data steward. This further strengthened the integration of FAIR data into the research cycle as the default.

2.5.3 Support

In the field of data management, support staff is at faculty level: faculty data stewards at central level, research data services at the library and the 4TU research data repository. These are existing and fully operational assets to make FAIR data possible. Recently, the Digital Competence Centre has started, in which research data managers and research software engineers are available to support departments and researchers to implement FAIR principles in data and research software, and recruitment of personnel is in progress.

The support staff is closely linked and forms a community TU-wide, linking different support services (Library, ICT) and the faculties.

2.5.4 Management information

Within Pure, the automatic upload of published datasets from sealed data repositories is at this moment not in effect. The library has planned the realisation of this upload, starting with the datasets out of the 4TU.ResearchData repository. The next step is the upload of datasets of researchers in other datacentres, nationally or abroad. If realised, the management information will be comparable to the information on open access publications during the quarterly meetings. This will provide management with a feedback loop on performance at FAIR data. At this moment, the information is more qualitative and process-oriented.

2.5.5 Results

At this moment, the results are mainly process-oriented, such as how many data management plans are made and how many datasets are archived for each CE department over the years. Please note that these overviews are incomplete, and thus not representative, because the infrastructure is not fully in place. The TU Delft library is currently working on a better connection between 4TU research data and Pure. The figures are only presented to give an indication of the current registration status. Figure 7 shows the number of data management plans (DMP) as created using the DMPonline tool per department per year. Part of the funder-required DMPs were created in Word templates (especially in the earlier years) and are not represented in these statistics.

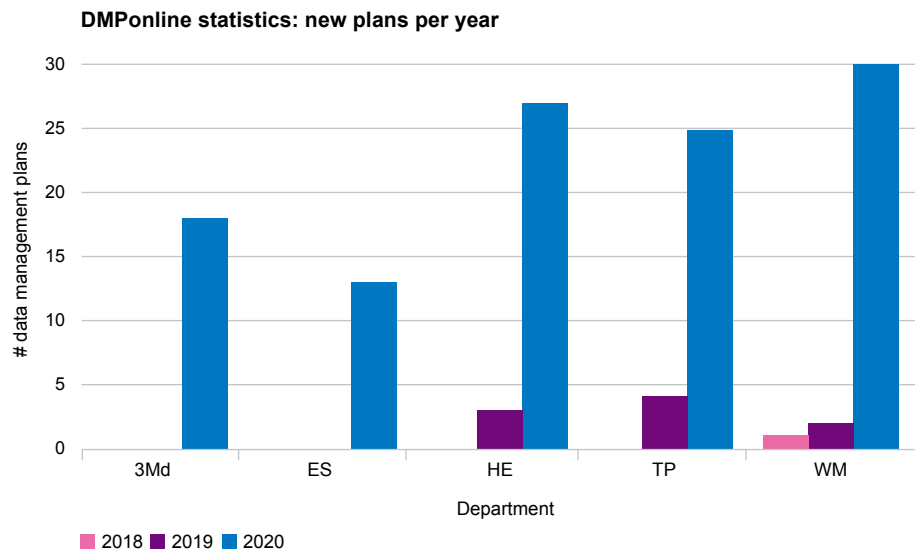


Figure 7 New Data Management Plans per department per year as created in DMPonline (note that this does not cover all DMPs, especially in the earlier years)

In Figure 8, the number of registered datasets in Pure is shown.

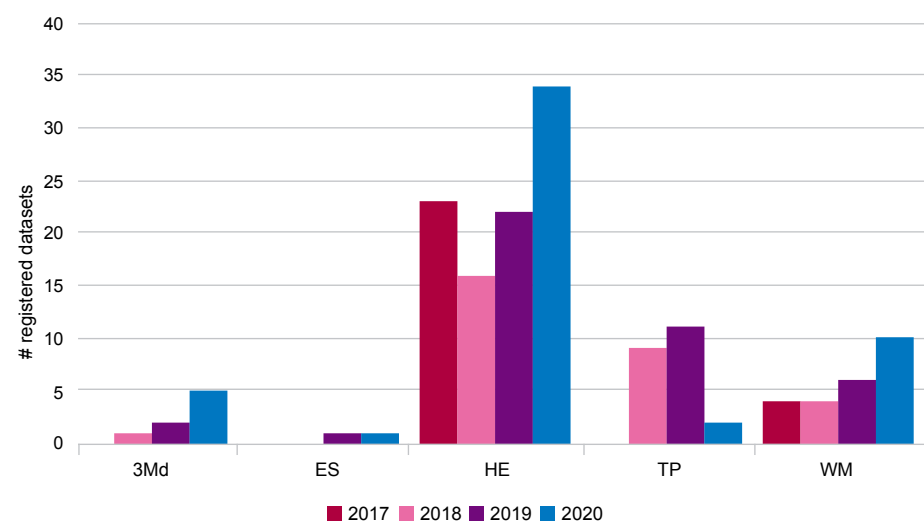


Figure 8. Registered datasets in Pure per CE department across the years 2017-2020. (Note that these numbers are incomplete. The numbers will increase when the infrastructure is fully in place) Source: Pure, reference date 20-05-2021

2.6 FAIR Software

2.6.1 Policy

Research software is defined as all code used in the research process, such as simulation models, (pre/post) processing scripts, analysis scripts and visualisation scripts. Management of software/code is integrated in the Faculty Data management policy of CEG. Research software could be a subset of research data or software that is used for other purposes. Therefore, software should also be managed in accordance to policy in order to be released and archived in a FAIR (Findable, Accessible, Interoperable and Reusable) way.

Early 2021, the Executive Board has approved the TU Delft Software Policy with guidelines for the implementation.

The policy includes the publishing of software as open source where possible and appropriate, considering the following:

1. Evaluate the possibility of commercial exploitation
2. Consider the risks of Intellectual Property Rights (IPR) infringement
3. Use one of the TU Delft's pre-approved open source licences
4. Comply with TU Delft requirements regarding software registration

2.6.2 Integration

Releasing FAIR research software is most effective and efficient when it is prepared and integrated throughout the research process. Software/code is therefore explicitly mentioned in the data management plan questions and highlighted by the data steward when consulted. A key point is that version control is always recommended. The 4TU. ResearchData repository facilitates research software with a DOI based on commonly used version control systems.

Various trainings (e.g. Software Carpentries) for PhD students and other staff is focusing on code management as an integrated part of the research process.

2.6.3 Support

The support of FAIR software is identical to FAIR data, with one additional service provided by legal service: support/advice on licensing of software and intellectual property.

2.6.4 Management information

Software is currently registered in Pure as datasets and not visible as a separate category. At this moment, management information cannot be delivered to monitor developments. Once the systems/infrastructure are/is in place, FAIR software will be a part of management information.

2.7 Outlook

General

The TU Delft Open Science Programme 2020-2024, with the inclusion of the evaluation of 2020 and the workplan for 2021, has taken a centrally-led approach. This approach will allow faculties to follow the TU Delft policies and facilitates in creating an eco-system of support for researchers and providing departmental management information. The overall aim in our faculty is the challenge to fully integrate Open Science in the practice of research and education. The strategy to reach this aim is to split the overall aim into sub goals for three projects: Open Access, FAIR data and FAIR software. These sub-goals will be discussed in terms of maturity in 2021.

With regard to the project of open access, the TU Delft Open Access percentage is set to a target of 75-80% for 2021. The strategy to reach this target is with several deliverables and the most important ones are to update the TU Delft Open Access policy, the Plan S implementation and the further implementation of the Taverne project.

With regard to projects of FAIR data and FAIR software, the aim is to develop policies and infrastructure and to connect both to each other. The strategy to reach this aim is with deliverables of policies, hiring data managers and research software engineers. In addition, support is developed and will be offered such as research data training, support software development, and support communities. Next to these deliverables, the TU Delft library is currently developing a database in Pure to register datasets and software. After the deliverables and the infrastructure are in place, then targets can be set and be monitored during departmental meetings.

Integration

A full integration of open access, FAIR data and FAIR software in the research cycle is possible. This will require awareness during moments of choice, particularly to choose for the Open Science option which is in most cases the starting point. Currently, researchers are invited for the introduction to “Faculty support for researchers” in which the support staff informs them on the different elements of Open Science. Integrating Open Science in the onboarding programme is the next goal. There is relatively limited need for training on Open access due to the current state of integration. We will focus on training in FAIR data and FAIR software. Currently, the following training is offered, in development or to be designed:

- Introduction “Faculty support for researchers” (faculty level)
- Data management plan (faculty level)
- Research Data management 101 (university level)
- Software Carpentries (4TU.ResearchData / university level)
- CodeRefinery (external collaboration)

For a researcher, the support (s)he receives is content-oriented and should not depend on organisational level. At faculty level, the data steward supports FAIR data and FAIR software and acts as liaison for university assets. Integrating the latest assets and further building an Open Science community will create the wanted sense of co-ownership in the university on Open Science on both the side of the researcher as well as the support staff. Although this greatly depends on developments at university level, the data steward is expected to optimise workflows and identify new needs.

Support

At this moment, no additional staff at faculty level is planned in a supporting role.

The outcome of the dialogue on the capacity needed and responsibility to provide training can change this.

At department/project level, the need for data managers and research software engineers is expected to grow. Temporary capacity can be requested at the Digital Competence Centre. For longer periods, these assets will be hired at department level, preferably funded out of research projects.

Management information

At this moment, the relevant management information is limited to open access.

The first aim is to extend this to include FAIR data and FAIR software when the policy and infrastructure are in place. The priority to create this management information at faculty level is low. Nearly all attention on FAIR data and FAIR software will be focused on increasing awareness and integrating processes in this phase. The content of the management information can thus develop from process to outcome indicators. An example of possible outcome indicators of FAIR data is the percentage of publications with an archived dataset or the (re-)use of datasets for validation or new research.

The current state of affairs on Open Science will be discussed using Open Science reports with departmental management meetings. In these meetings, root causes and solutions on OA publications, FAIR data and FAIR software will be discussed.



3. PhD candidates, the (Faculty) Graduate School and related issues

3.1 Background

For more than 10 years, TU Delft has explicitly acknowledged the key role played by PhD candidates for research performance and, in general, for the entire life of the University community. The realisation has grown that the success of a PhD is a **shared responsibility** of the entire University rather than being only dependent on the promotor/co-promotor. Consequently, a holistic effort was needed to unlock the full potential of PhD candidates and to reduce the exceedingly long duration of PhD theses. In 2012, the Graduate School was launched, organised in a central University Graduate School and Faculty Graduate Schools. Key components of the Graduate School are as follows:

- a. A series of formalised steps to monitor the progress of the PhD, align expectations and to make sure that the PhD candidate can develop his/her full potential reaching the goal of producing exciting science and thereby becoming an *independent researcher* within four years. These steps include the GO-NOGO meeting typically held 9-12 months after the beginning of the PhD and the 2nd year and 3rd year Progress Meetings (YPM). After some initial resistance and difficulties, most supervisors are now well-acquainted with the new reality and, more importantly, PhD candidates increasingly recognise these meetings as a key opportunity they have to (re)define their project (see below) and realise their ambitions.
- b. The Doctoral Education (DE) program was launched with the goal of strengthening the PhD candidates. In the DE, PhD candidates are required to acquire a number of credits in discipline-related research and transferrable skills. Credits are obtained in a variety of ways, from courses to summer schools, from paper-writing to conference presentation and from MSc thesis supervision to Teaching Assistant activities.

All these activities are supported by a dedicated software package DMA, which allows PhD candidates and other involved members of the University community to access relevant data. Being able to monitor in detail the progress of PhDs has been a key step in the strengthening of the Graduate School and also plays a key role in identifying possible bottlenecks (see below).

Having reached an acceptable level of efficiency, the University and Faculty Graduate Schools have in the last few years stepped up their activities. We acknowledge the full support of the University as a whole and of the Civil Engineering and Geoscience Faculty.

3.2 General challenges

3.2.1 The triangle to PhD success

Possibly one of the most important “cultural” changes being pursued is the knowledge that the success of a PhD depends not only on the quality of the PhD candidate her/himself but also on that of the supervising team and of the project structure (Figure 9). PhD development and all related activities are geared to the constant improvement of all three components.

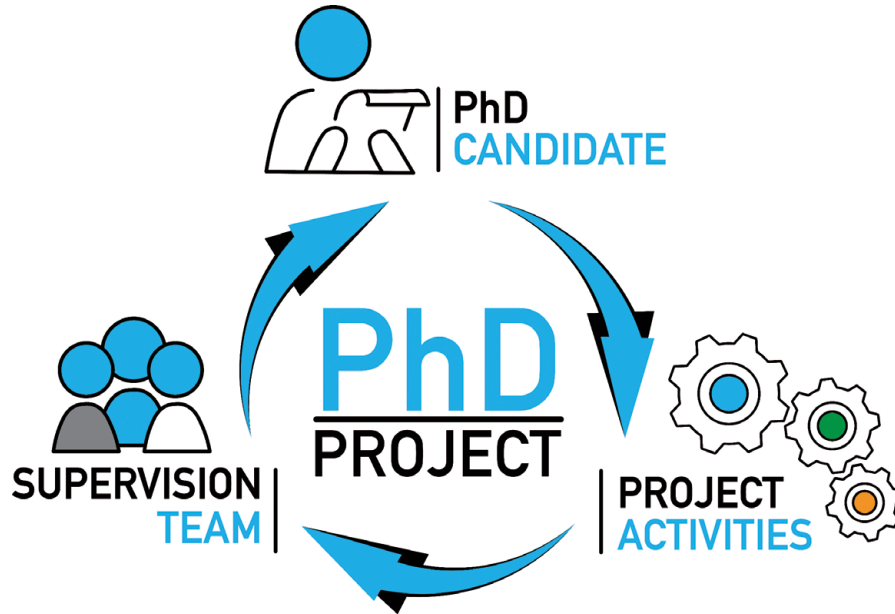


Figure 9 - The triangle of PhD success

3.2.2 Empowering PhD candidates

As a Faculty Graduate School, we believe that empowering PhD candidates and encouraging them to play a proactive role in all meetings and throughout the entire PhD path, is a long-term engagement and a fundamental step in improving PhD success. The Faculty Graduate School is investing a substantial amount of energy in communicating to PhD candidates the notion that they are “captains of their boats” and should prepare meetings and make sure that they have all the information needed. In the view of the Graduate School, empowering PhD candidates is a fundamental component of ensuring the success of PhD projects.

To facilitate this process and to give PhDs an even stronger voice, a PhD council was founded in 2017, composed of PhD representatives of all departments of the Faculty. The PhD council meets on a monthly basis with the Director of the Faculty Graduate School, has organised a number of highly successful PhD days and represents a key bridge between the PhD community on the one side and the Faculty Graduate School and the Faculty staff on the other. As of mid 2020, one of the PhD Council members represents the PhD Council in the CEG Employee Council (CiTG OdC) as an elected member of that Employee Council. Moreover the dean has monthly meetings with representatives of the PhD council.

As a further support for PhD candidates, a system of mentors is in place by which a mentor (a member of staff of the Faculty) is assigned to a group of 10-15 PhD candidates. The FGS has also opened a MS Teams channel dedicated to the best practices developed by the various departments.

3.2.3 Improving supervision

The notion that the success of PhDs is a shared responsibility bears the consequence that the Faculty should take an active role in improving the quality of the supervisors,

promoters and co-promoters alike. In the Civil Engineering and Geosciences Faculty, this is implemented in the HYPPR (Half-Year PhD Progress Review) meetings. Twice a year, the Director of the Faculty Graduate School, together with the FGS coordinator, HR representative and the Department manager, meets the Department Chair to discuss the specifics of the progress of PhD candidates. Behind closed doors and in a fully confidential manner, the performance of single promoters is discussed, criticalities are identified and improvement strategies defined. On a yearly basis, the Director of the Faculty Graduate School reports his findings to the Dean of the Faculty, who is the formal “supervisor” of Professors. HYPPR meetings have proven extremely useful tools to identify criticalities and, more in general, in spreading the notion that the Faculty and its Graduate School consider the quality of supervision a first-order challenge.

3.2.4 PhD candidate well-being

The well-being of PhD candidates is obviously key for their success and, thereby, for the success of the University as a whole. Aware of the major investment these individuals make in choosing to perform a PhD in Delft, the (F)GS is fully engaged in ensuring that the PhD path is scientifically and humanly exciting and productive. Major efforts are deployed to make sure that PhD candidates are welcomed in the respective departments and research groups and that they can develop their work as smoothly as possible.

The (F)GS also provides a number of support programmes inclusive of psychological coaching when needed.

These efforts have been further strengthened since the outbreak of the Covid-19 pandemic with initiatives such as buddy systems and coaching.

3.3 The path from PhD selection to successful completion

3.3.1 Selection

Building on the recognition that delays in PhD projects are often associated with an insufficient level of PhDs, the selection process has been made stricter and more transparent. A four-eye principle is presently implemented by which selection interviews are conducted by at least two staff members; these rules are now followed by all departments. Members of the Committee are also asked to produce a short description of how the selection took place and what possible points require further attention. Criteria and workflow of PhD selection are extensively addressed in booklets shared with all staff members. To tackle shortcomings and delays associated with insufficient knowledge of the English language, an English proficiency test (at least TOEFL 100 or IELTS 7.0 overall) has been required since the beginning of 2021. PhD candidates are also strongly encouraged to take English proficiency courses during the first year of their PhD.

3.3.2 GO-NOGO and yearly progress meetings

From its beginning, the Graduate School has defined a number of formal milestones in the PhD path to monitor the progress of the project, to identify challenges and, most importantly, to create new opportunities. The FGS has invested significant energy and time in raising the awareness of staff members and PhD candidates alike of the importance of these meetings and encouraging the various stakeholders to use them at their full potential. The message is conveyed that, rather than being a bureaucratic nuisance, these meetings are key opportunities to assess the progress of the project and, at least as important, identify new exciting and challenging goals. For the PhD candidates in particular, these meetings are a key step to align expectations with those of the supervising team and identify weaknesses and opportunities in the project.

The first formal step, typically after four months, is the formulation of a **PhD agreement** between the PhD and supervisors in which the nature of the project and a course time plan is defined. The **GO-NOGO** meeting is a key step in the PhD path and, more

or less, the last moment when a PhD contract can be terminated. Expanding on the more traditional approach, we see the GO-NOGO as an occasion to judge and identify improvements not only for the PhD herself or himself, but also of the other two key components, namely the quality of the supervising team and the structure of the project itself (Figure 9). To facilitate this process, the GO-NOGO meeting is led by a committee composed of at least three members, including the co-promotors and supervisor and an independent member. The promotor is present but is not a member of the committee. The goal of the committee is to judge the potential of the PhD candidate in order to successfully complete the PhD within four years, as well as to identify ways to strengthen his or her development, to identify weaknesses in the project planning, to identify other opportunities which might be taken and to check that all knowledge is available in the supervising team. It is during the GO-NOGO meeting that agreements are made on, for instance, the number of papers to be published, teaching duties and all other relevant topics. The **2nd and the 3rd year YPMs** are the next formal steps in the PhD path. They are designed to identify weaknesses and bottlenecks and, even more importantly, to define new and exciting opportunities. Strong emphasis is put on the 3rd year meeting, in which all contents of the thesis should be defined making sure that the thesis is completed within the anticipated four years.

As a Faculty Graduate School, we regularly monitor the quantitative performance of the different promotors in having the GO-NOGO and YPM meetings. As PhDs with problems typically have a history of no/few/poor milestone meetings, we also look regularly at the quality of the resulting reports.

3.4 Specifics from previous visitation

3.4.1 Dropout rates

High dropout rates have been mentioned as a point of attention in the previous visitation. The data at the moment of writing are shown in Figure 10; raw data are provided in the appendix. The number of PhDs interrupting their path before or immediately after the GO-NOGO is generally <5% and generally stems from the realisation of the candidate that the PhD life is quite different from what was expected, as well as from not-strict-enough selection; in our view, these numbers are physiologic.

The number of discontinuations after 18 months is significant and oscillating. As the University has basically no way of terminating ongoing contracts after the GO-NOGO, these discontinuations reflect decisions of the candidates themselves¹. To understand more of the underlying reasons, we have conducted some interviews and believe this decision reflects the recognition of candidates that the PhD life is not what they wanted (see box).

Student M decided to interrupt her PhD at the end of the 2nd year. We were somewhat surprised because we, as Graduate School, had no signal that the candidate was experiencing any negative situation. M. has always been a brilliant student, all the way back in high school; she had performed well in an excellent MSc program and, not surprisingly, she was offered various PhD projects within TU Delft. Without thinking too much and without being challenged too much, she simply walked through this wide open door, only to discover that she did not fully appreciate the somewhat isolated research conducted by a PhD. Having also spoken with the promotor, the lesson we drew is that there needs to be more alignment between expectations of the candidate and of the supervisors.

¹ To increase flexibility, the University has recently decided to split the contracts of PhDs in two parts of 1.5 and 2.5 years.

Drop out (#) - Civil Engineering departments
reference date: 1 april 2021

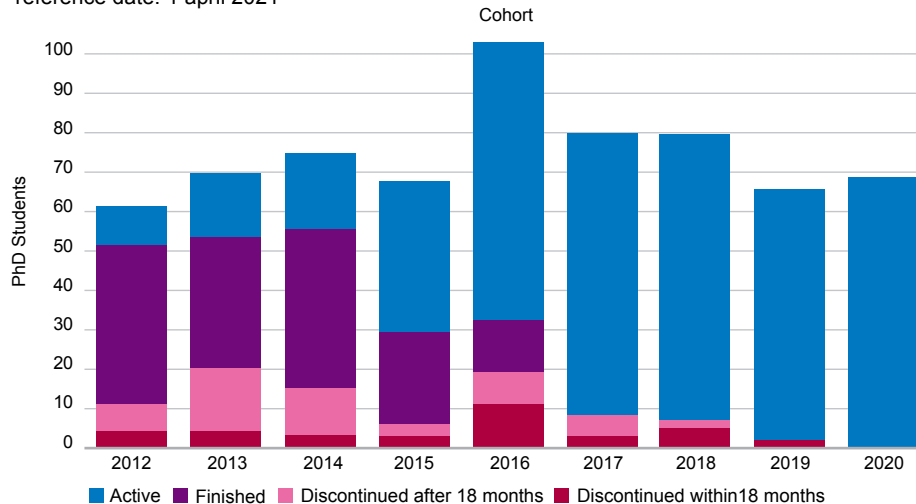


Figure 10 - Status of PhD candidates. Numbers of discontinuations after 18 months of cohorts 2017 and younger have limited value as a substantial portion of candidates has not ended yet the PhD.

3.4.2 GO-NOGO Compliance

As mentioned above, the GO-NOGO meeting plays an important role in the development of a PhD candidate and his/her project, indeed far beyond the initial goal of deciding if the PhD candidate is fit to bring his/her project to successful completion. The GO-NOGO plays an important role in empowering PhDs and is key in making aware the supervision team of the shared responsibility of the project. As shown in Figure 11, we observe a significant increase in the number of GO-NOGO meetings taking place and submitted reports. We believe this is a significant achievement of the GS which suggests an important shift in the attitude of the University towards PhD candidates.

3.4.3 Homegrown vs PhDs from outside

A remark was made on the “too large percentage of homegrown PhDs”. Our data suggest that this percentage varied in the last eight years between 25% and 35% (Figure 12). In our view, this percentage is far from deserving the attribute of “too large”. We believe that TU Delft MSc students are provided with high-level education and are well-known to staff.

Gonogo compliance for active PhD candidates (excl IHE - Civil Engineering departments)
reference date: 1 april 2021

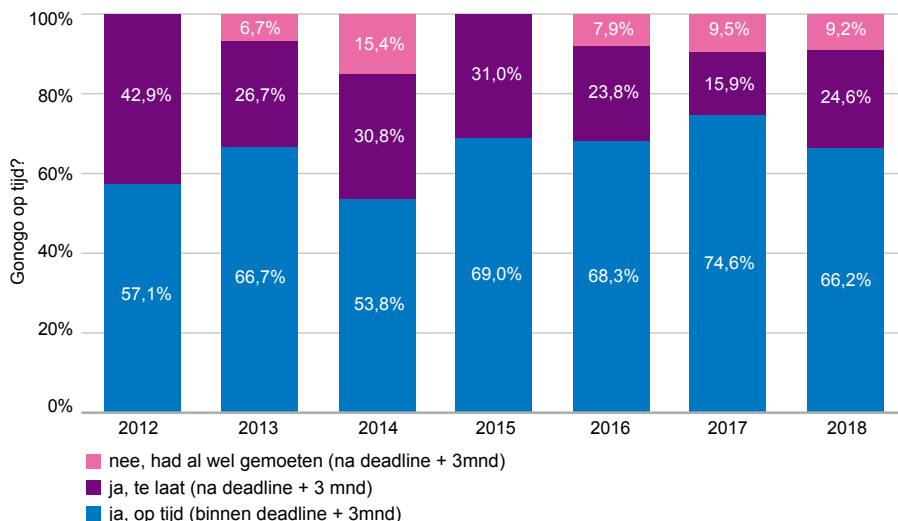


Figure 11 - GONOGO compliance

Previous qualification - Institute (%) - Civil Engineering departments
reference date: 1 april 2021

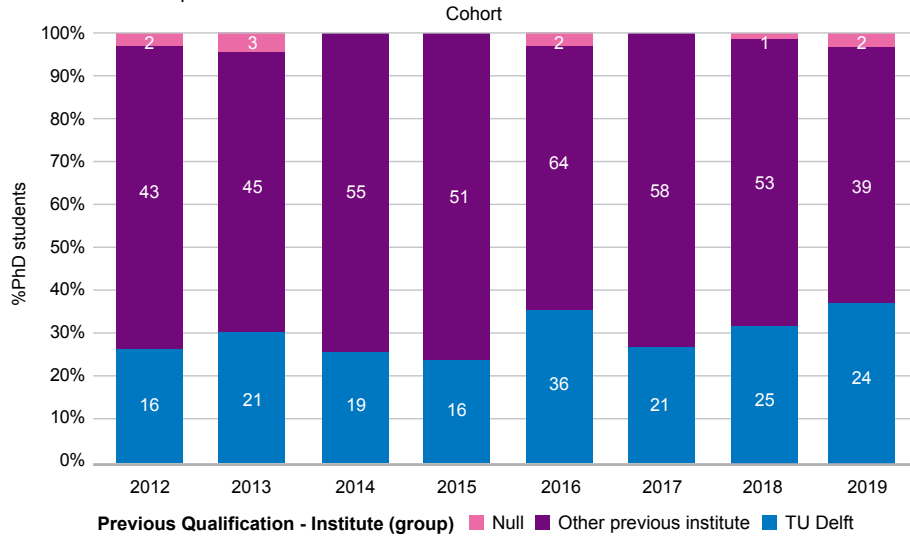
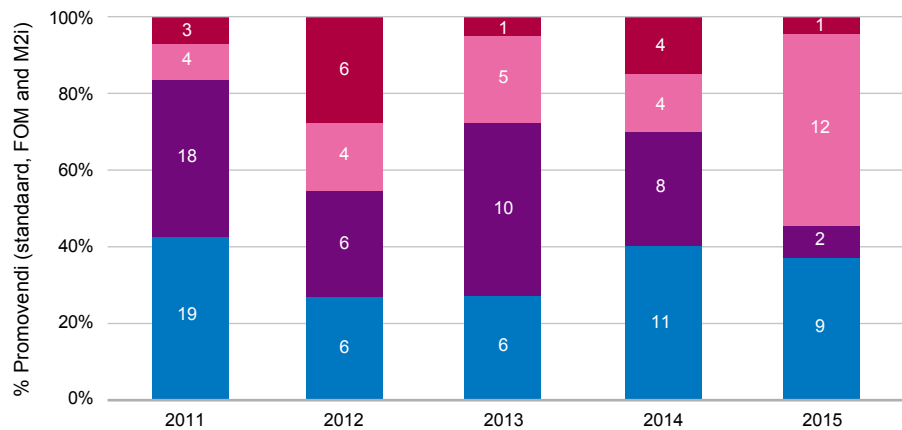
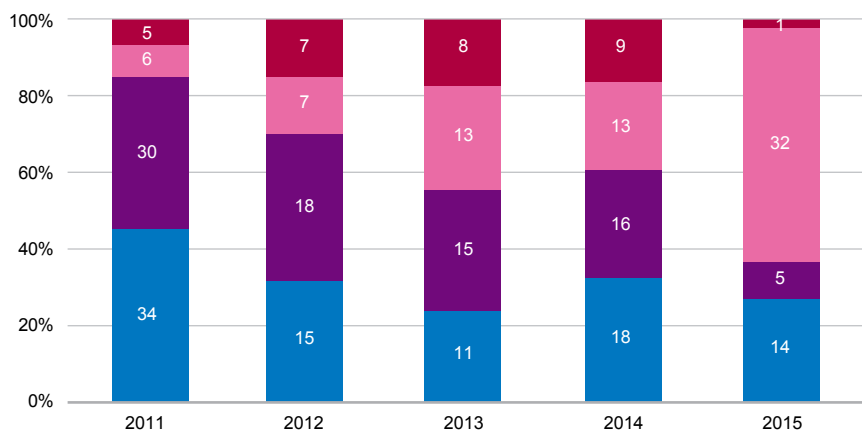


Figure 12 - homegrown vs “external” PhD candidates

Status VSNU category Standaard, FOM, M2i - Civil Engineering departments - PhD candidates who discontinued within 18 months excluded
reference date: 1 april 2021



Status VSNU category Standaard, FOM, M2i & Bursaal - Civil Engineering departments - PhD candidates who discontinued within 18 months excluded
reference date: 1 april 2021



status promovendi (inclusief rendement)

■ > 5 jaar gepromoveerd ■ gestopt
■ < 5 jaar gepromoveerd ■ nog bezig

Figure 13 - Data on PhD duration

3.4.4 PhD duration

The exceedingly long duration of PhD projects is one of the main challenges facing the University and the Faculty. With the partial exception of PhD candidates who pursue their project while working, typically full-time, in industry, we see no justification for an overlong PhD duration. The general approach and the specific actions undertaken have been discussed in the previous parts of this document. The results shown in Figure 13 can be obviously interpreted in different ways but, admittedly, they do not convey the message we would to see, namely that the duration time is substantially decreasing. A number of proxies have been presented above which indicates that we are on the right track, but the positive results are still to come. As the first years of the Graduate School (basically until 2015-16) were essentially dedicated to bringing the “machine” to a good level of operation and that limited energy was invested in the issues underlying long PhD duration, we are confident the results will be visible over the next few years. Specific action has been taken to decrease the impact of delays associated with the Covid-19 pandemics on PhD completion. While we consistently communicated the message that it is the responsibility of the supervising team to identify activities alternative to those made impossible by the pandemics, a scheme has been implemented allowing a three-months extension for PhDs in specific and grave need.

3.5 Evaluation, perspectives and future challenges: the big picture

The various initiatives taken by the (F)GS to uplift the PhD performance have been mentioned in the previous parts of this document and will not be further elaborated. Looking at larger trends inside the University and the surrounding society, we believe a number of developments can be defined which will require some reflection on our perception of PhDs. We believe that these challenges are opportunities for us to improve our mission. Improving the PhD experience requires a major cultural shift towards the knowledge that PhD success is a shared responsibility of all stakeholders, namely University staff and PhD candidates. Solving some of the problematic issues identified in these years requires a significant improvement of our Academic Culture, which includes topics such as diversity, integrity and human resources. In this respect, improving PhD performance is organically linked to the work of the Academic Culture Committee and related initiatives.

- At TU Delft as in other universities, the goals of a PhD as well as the path to reach them are only vaguely defined. A graphic illustration of this is the large variety of guidelines as to the number of papers PhDs are required to publish and how strict these requirements should be. In doing this, the University “outsources” the judgement to the quality of a thesis to journals and respective editors. Is this a welcome development or should the University develop new, more informative forms of judgement of the PhD thesis?
- The Academic community agrees that the fundamental goal of a PhD trajectory is to form an independent researcher within the prescribed four years. Obviously, this can happen at different levels and requirements of the promotor to “achieve the highest standard” should not translate in substantial delays in PhD completion.
- TU Delft, like other technical universities, has a substantial number of PhD candidates who write their thesis while working in companies. While these candidates fulfil a necessary bridge function between university and industry, the question should be raised as to how far this model adheres to the generally accepted idea that a PhD candidate should obtain his/her own data and, for instance, not simply use data generated by the candidate and his/her company.
- In a large number of occasions, PhDs have expressed their frustration about the insufficient transparency of the University and on the rights they have. A similar concern is regularly manifested by postdocs and assistant professors. In the view of the FGS, there is a lot of mileage to be gained in this domain. Widespread and real transparency can have a major impact on the motivation of PhD candidates and, thereby, improve their overall experience.



4. Academic Culture at the Faculty of Civil Engineering and Geosciences

4.1 Background & Process

During the kick-off meeting for the 2021 midterm assessment, a decision was made to form a committee tasked with assessing the daily practice of the research unit with respect to academic culture, as well as how the culture fosters or hinders the attainment of the Faculty's strategic aims. To properly assess how the culture is perceived by the majority of scientific employees, it was decided not to include any individuals in higher-ranking management roles in the committee. The following criteria were defined for its composition:

- Members are > 50% PhD-candidates or Postdocs.
- Members are < 25% in a management role.
- Workplace diversity is balanced with attention to identity, male/female, country/continent.

This led to the Academic Culture Committee (ACC) as presented in the table below, where its members should be viewed as selected individuals as opposed to departmental representatives.

Eliz-Mari Lourens (Chair)	Assistant Professor	South African/Dutch; female
Florentia Kavoura (Secretary)	Postdoc	Greek; female
Florencia Balestrini	PhD	Argentinian; female
Leon Hombergen	Assistant Professor	Dutch; male
Alexandra Rocio Urgilez Vinueza	PhD	Ecuadorian; female
Riccardo Riva	Associate Professor	Italian/Dutch; male
Ali Vahidi	PhD	Iranian; male
Meng Wang	Assistant Professor	Chinese; male

The committee was split into groups addressing, respectively, diversity, openness and inclusivity, research integrity, and social safety. During a period of just over 2 months, the groups gathered information on these topics through interviews, surveys, and qualitative and quantitative research. Although the focus was on the Faculty of Civil Engineering and Geosciences, comparisons were also sought with other universities, both nationally and internationally.

The findings of the committee were presented to the Management Team of the Faculty on May 7th, 2021. In what follows, these findings will first be summarized. A brief discussion of the meeting with the Management Team will subsequently be given, focusing on the conclusions made based on the discussions that took place during that meeting.

4.2 Diversity, Openness & Inclusivity

4.2.1 Policies and regulations at the TU Delft

At the university level, the senior leaders, staff, and students are encouraged to embody and embrace the power of differences through the Strategic Framework 2018-2024 and the diversity policy. The Diversity and Inclusion (D&I) Office of the TU Delft aims at making a sustainable impact on improving the campus culture, the demographic composition, and in elevating educational standards. The D&I office mainly focuses on seven thematic areas:

- Gender equality
- Gendered Research and Innovation (GRI)
- Study and work success and representation
- Institutional support & wellbeing for students and staff
- Further professionalize recruitment practices vis-à-vis diversity and inclusion
- Religion and spirituality
- Disability support services for staff and students with disabilities

In the understanding of the ACC, the policies and activities supported by the D&I office at TU Delft are still being developed/adjusted and advanced, so it is not yet clear which specific actions will be taken in order to address the aforementioned thematic areas. The D&I Office is, however, planning a diversity week in October, when also a campus-wide diversity survey will be conducted.

In terms of gender diversity specifically, The *Delft Technology Fellowship* aims to improve the recruitment, selection, career development and retention of female senior staff. It offers faculty positions to internationally recognized female scientists and engineers and provides additional resources to female assistant professors in order to accelerate their promotion to associate professor. Our Faculty supports the Fellowship, and recruits female scientists through the Fellowship. Specifically, over the past 6 years, the CEG Faculty participated in all 6 rounds of the DTF, and recruited 6 female scientists via this route, three of which are Associate Professors.

4.2.2 Experiences within the Faculty

Diversity

Diversity is a broad term referring to people from a range of different social, ethnic, religious, and cultural backgrounds, of different genders and sexual orientations, to people that are physically or mentally handicapped, etc. The focus here will be on gender diversity, which was identified as a point of concern for the CEG Faculty specifically, already in the previous research review.

The concern resulted in the bold initiative of only starting selection procedures for vacancies if 50% of the candidates on the shortlist were serious female candidates. As a result, 50% of the 22 Sectorplan/van Rijn vacancies were filled with female scientists

last year. The percentage of female staff increased, but the ambitious goal of 23% female senior staff overall by 2020 was not met. As shown in the table 4, female senior staff is now at 16,9%.

Table 4: Percentage women per staff category (based on headcount)

		2017	2018	2019	2020
Faculty members	Assistant professor	21,9%	21,9%	24,4%	27,5%
	Associate professor	16,5%	14,7%	12,3%	16,9%
	Full professor	6,4%	8,2%	8,2%	8,6%
	Total	13,9%	14,1%	14,3%	16,9%
Other Research staff	Researchers	30,7%	29,9%	30,5%	26,0%
	Total	30,7%	29,9%	30,5%	26,0%
Other	Support staff (research)	13,9%	13,6%	12,9%	13,8%
	Total	13,9%	13,6%	12,9%	13,8%

Source: HR system, reference date: 01-02-2021

Faculty: CEG | Department: 3MD, ES, HE, WM and TP

The ACC was of the opinion that the Faculty still suffers from a lack of awareness of implicit biases, and their consequences for recruitment and promotion processes especially. This pertains not only to gender diversity, but to diversity in general. On the basis of interviews with employees previously employed at other universities, the committee concluded that the discussions (and implemented procedures) in our faculty is still relatively immature when compared to many other universities, both nationally and internationally. Examples of recruitment procedures designed to eliminate/minimize such bias at other universities were presented as examples.

Networks and organizations

At TU Delft awareness of diversity is growing. Most certainly in our students, but also in our staff. The staff has already organized themselves in professional networks like DEWIS for female scientific staff and TrueU for all LGBTI-staff. The ACC expects that in the future more networks – some formal and some informal – will be organized including more minority groups (e.g. staff with special needs). Similar initiatives are expected in the student populations. The importance of recognizing these organizations were raised, and empowering them to be in touch, as they can generate important signals to the Faculty, and improve awareness in staff.

Hierarchy

The ACC reported that, when talking to faculty members that joined the TU Delft after having worked in other universities outside the Netherlands (especially the UK), a recurring comment was that the faculty is much more hierarchical than what they were used to. In some cases, a feeling of involvement was lacking because of this. An example here is the inclusiveness and transparency of the Faculty Management Team, which was also commented on in the previous research review.

Chinese and Russian colleagues

Recent reports from Dutch media speculated on the espionage of Chinese and Russian researchers in Dutch Universities. The increasing media attention can influence the perceived safety and well-being of colleagues with Chinese and Russian origins working at the Faculty. TU Delft has initiated a Greater China Team focusing on the university-wide strategy when collaborating with China. There were cases when Asian colleagues and their family experienced racial discrimination outside the university since Covid-19. The ACC suggested that the Faculty follows these developments closely.

4.2.3 Suggestions for the future

To give more structural attention to diversity, openness, and inclusivity, the ACC proposes the establishment of a CEG Diversity and Inclusion Team. Representation from the faculty members, HR, and the Student, PhD, and Works councils is suggested. A few initial points of attention for this committee are listed in their report, including (further) professionalization of recruitment processes in view of implicit biases, exploring ways to make diversity more visible and recognizable (especially in decision-making bodies), and ways to make the faculty hierarchy more transparent. The latter is not meant in terms of reducing the perceived hierarchy, but in terms of making the decision-making processes more transparent, in order to open the door for an increased influence of young/diverse staff members on faculty, department, or even section policy.

4.3 Research integrity

4.3.1 Policies and regulations at the TU Delft

The TU Delft Strategic Framework 2018-2024 is addressing research integrity as one of its core values and sets the goal of setting up an integrity policy that protects scientific data and personal data in line with EU and Dutch directives. Details can be found in the TU Delft [Vision on Integrity 2018-2024](#) and in the [TU Delft Code of Conduct](#), which in turn is based on the [Netherlands Code of Conduct for Research Integrity](#), adopted by the Association of Universities of the Netherlands (VSNU).

Here we reproduce the key concepts from the Code:

- *Honesty*: it means, among other things, reporting the research process accurately, taking alternative opinions and counterarguments seriously, being open about margins of uncertainty, refraining from making unfounded claims, refraining from fabricating or falsifying data or sources and refraining from presenting results more favorably or unfavorably than they actually are.
- *Scrupulousness*: it means, among other things, using methods that are scientific or scholarly and exercising the best possible care in designing, undertaking, reporting and disseminating research.
- *Transparency*: it means, among other things, ensuring that it is clear to others what data the research was based on, how the data were obtained, what and how results were achieved and what role was played by external stakeholders.
- *Independence*: it means, among other things, not allowing the choice of method, the assessment of data, the weight attributed to alternative statements or the assessment of others' research or research proposals to be guided by non-scientific or non-scholarly considerations.
- *Responsibility*: it means, among other things, acknowledging the fact that a researcher does not operate in isolation and hence taking into consideration – within reasonable limits – the legitimate interests of human and animal test subjects, as well as those of commissioning parties, funding bodies and the environment.

On ancillary activities the CEG Management Team approved on October 5th 2018 a policy which is approved as per the Sectoral Scheme Ancillary Activities and the additional conditions:

1. the ancillary activities are reported every two years via the online registration form: TU Delft: Ancillary activities
2. the Department Chair and the Dean approve;
3. the ancillary activities are reported yearly within the Department during a Department meeting;
4. if the ancillary activities are performed during regular working hours, any income will be transferred to the Department, while agreements about spending of the income can be made with the Department Chair.

4.3.2 Experiences within the Faculty

Research Integrity is a key principle for all academics. It is hence assumed that all researchers, from PhD candidates to full professors, know its meaning and uphold it at all times. As a result, the ACC had the impression that it is not often explicitly discussed. A similar comment was raised by the assessment committee in the previous research review. In response to this, a short questionnaire was distributed to the members of the Faculty Management Team and to some section heads on March 26th, 2021. The purpose of this questionnaire was to verify, next to the personal experience of the members of the ACC, whether research integrity is explicitly discussed within the Faculty, and to collect the viewpoints of the highest level in the faculty hierarchy.

The questionnaire can be found in Appendix 4.7.

From the responses obtained, the principle of responsibility stood out, for different reasons: on the one side because responsible behaviour leads to upholding the other principles, but also as a point of attention, because it might not always be clear with whom the responsibility lies. It was also commented that data privacy rules and handling of potential conflicts of interest should receive more attention, because disregarding them could damage both the organization and individual researchers. Besides, it was commented that part of the problem with conflicts of interest could be due to conflicting university policies (e.g. when dealing with intellectual property and patent policies). It has also been suggested to clearly explain what is meant by scrupulousness, since it is a term that could have different meanings.

No mention of a specific training was received, apart from a Graduate School course compulsory for PhD candidates. Research integrity does occasionally arise in discussions, at the individual level. It is sometimes discussed during R&D meetings, when the occasion arises and especially in relation to writing and publishing, but not on a regular basis. It was also noted that the Data Management Plan is a good tool to address research integrity.

It is expected that the staff is aware of the Code and Roadmap, but mostly through faculty channels. There do not seem to be specific actions regarding awareness at department level.

The topic of research integrity was by some acknowledged as in need of more specific attention.

Apart from the questionnaire, the ACC also collected feedback on research integrity from colleagues. One of the issues raised was transparency/openness towards the wider academic community. While a data management plan is required for PhD students by TU Delft and for research projects financed by some funding agencies such as NWO, the execution of the plan and the quality of the data is not always checked. The reproducibility of the work from the data may not be guaranteed.

4.3.3 Suggestions for the future

The ACC encourages the Faculty to make discussions about research integrity a regular point of attention and discussion. More specifically, it is suggested that a dedicated training about Research Integrity could be offered to all new employees, and repeated every few years through their transition in all career levels from junior researchers to mentors and leaders, with possible embedment in the tenure track. Research Integrity could also be explicitly mentioned in the R&D meetings, by requesting employees to write a short reflection on it.

Concerning potential conflicts of interest, it is suggested to consider explicitly addressing the issue at the beginning of every department and strategic meeting, by asking the people present whether they have any conflict with respect to individual agenda items. If that is the case, they could temporarily leave the room.

Execution of the data management plan and quality of data could be impartially checked by the faculty data steward to ensure reproducibility of the research work.

Finally, the various screens around the faculty (at the coffee machines, in the corridors) could be used to remind students, staff and visitors about the TU Delft Code of Conduct.

4.4 Social safety

4.4.1 Policies and regulations at the TU Delft

The coordination of the TU Delft policies and activities on integrity lies with the Integrity Office. Here, the focus is on social integrity. As part of the Association of Dutch Universities (VSNU), TU Delft designed a statement on social safety in which they speak out against undesirable behaviour. Additionally, this statement mentions the commitment of Dutch universities to provide students, employees and visitors with a safe and respectful environment, where any type of undesirable conducts, such as harassment, aggression, bullying or discrimination are not tolerated.

Social integrity is further addressed in the TU Delft Code of Conduct and its 'Vision on Integrity 2018-2024', mentioned earlier. The vision elaborates on the wish to 'offer employees, students and guests an environment where everyone feels welcome and where everyone treats each other with respect.' It is stated that all members of the TU Delft community must treat each other with respect, irrespective of their culture, religion, ethnicity, socio-economic background, gender or sexual orientation. The Vision on Integrity also proposes an infrastructure regarding information, regulation, reflection, consultation, investigation and coordination. It is stated that it is of utmost importance that all members of the TU Delft community are aware of the TU Delft's integrity policy. But also that awareness of existing policies is not enough: rather, students and staff should be encouraged and feel safe to discuss integrity dilemmas. This requires continuous attention for the topic within all levels of the organization and for all dimensions of integrity.

Situations involving inappropriate behaviour, such as intimidation (sexual or otherwise), bullying, aggression or conflicts (personal or work-related) are covered by the TU Delft Regulations for complaints about undesirable behaviour. An employee, student or third party who claims to have been subjected to inappropriate behaviour should file a complaint. The complaint is passed to a complaints committee, which then makes a recommendation to the Executive Board. If necessary, the Executive Board can impose disciplinary measures on the perpetrator. For assistance, advice or support in this area, a confidential advisor is available at the TU Delft. This confidential advisor for undesirable behaviour is an external, impartial person, who ensures adequate help for people that encounter undesirable behaviour. Additionally, TU Delft has an Ombuds officer for staff who can help individuals or groups of staff to resolve their work-related questions, dilemmas or conflicts. The Ombuds officer acts as an intermediary and is independent and impartial.

4.4.2 Experiences within the Faculty

Although adequate policies and regulations are in place at the university level, the ACC concluded that for social safety – just as for diversity – there is still some discrepancy between what is arranged at national or TU level, and what is operational at the Faculty. Based on their interviews, 85% of reported cases regarding social safety are related to international employees, which means that cultural differences play a significant role. The advisors at the university level indicated that most of the problematic cases at the CEG Faculty are related to intimidation, harassment, and bullying.

Concerns regarding social safety come back in the faculty-specific Medmon statistics, where for the CEG Faculty 25% of the employees indicated that they have experienced one or more instances of undesirable personal treatment by colleagues, supervisors, students and/or strangers. More specifically, the ACC received signals of authoritarian professors not accepting deviations from the general direction they set out for their group. Also more serious cases including patterns of misconduct not being recognized and acted upon by superiors, were reported. Escalation routes are often not used because they are unknown or untrusted. According to the Medmon statistics, only 56% of the employees that experienced undesirable personal treatment reported the incident(s) to their superiors, HR advisor, confidential advisor, or another person.

The confidential counsellor believes that more awareness of the TU Delft Code of Conduct and the importance of third party counsellors must be created. Many people still have no knowledge about the code and under such circumstances, a space is permitted for people to repeat their bad behaviour.

The ACC consequently concluded that there is not enough communication, which negatively affects implementation and the creation of awareness. Additionally, the perception of some of the available information related to social safety is indeed subjective. As an example, the meaning of bullying is not explained, while it could have different meanings to different people. Most people do not intend to make fun of someone and create an uncomfortable environment, but they sometimes do not realize their behaviour is inappropriate within the international community they find themselves in. This lack of information comes from a lack of education and communication. Through PhDs, it was brought to the attention of the ACC that due to religious beliefs, functional disabilities, English fluency (accent) and dietary restrictions/choices, some people feel bullied by colleagues and senior researchers.

4.4.3 Suggestions for the future

A problem that seems common in engineering schools is the lack of communication and interaction. The route to discuss undesired behaviour should be much clearer, something the Integrity Office is working on as well. The ACC stresses that it is important to ensure that especially the people with different nationalities/religions/beliefs are heard, and feel included.

It is recommended to consider appointing a confidential advisor for the Faculty specifically, and to communicate his/her existence more broadly. Whether faculties should have their own confidential advisor and how to ensure that he/she is well trained and equipped to do the job have been points of debate, however, of which the ACC was unaware. Also the importance of monitoring the situation is raised, where systematic recording by the confidential advisor and/or Ombudsman, action plans, and plans for periodic attention from management is suggested. It is suggested that the listed advices with regard to social safety should also fall under the responsibility of the future CEG Diversity and Inclusion Team.

4.5 Presentation to the Management Team

The ACC was invited to present their findings to the Faculty Management Team on May 7th, 2021. During the meeting it became apparent that there are indeed points on which the perception of management versus lower-level scientific employees diverge. The differences were discussed, and the value of the ACC in identifying these differences, was underlined. It also became clear that for some points of attention raised by the ACC, processes were already initiated (e.g. implicit bias trainings). Due to its composition, the committee was not aware of some of the actions already undertaken at the management level.

In the same meeting Prof. Giovanni Bertotti was appointed as the new Diversity Officer of the Faculty.

4.6 Summary

The academic culture at our faculty needs to adapt to the transition of our university to a larger, more international, and more diverse organization. This is a positive process, but not one with only positive (side-)effects, and requires supervision and monitoring. Some values are essential and non-negotiable; others will be changed in time.

The process needs leadership and professional guidance. Assembling the ACC was a valuable first step in giving this process the attention it deserves. The mandate and

time given to the ACC to do their assessments were (consciously) ill-defined and limited, however. For this reason the ACC explicitly refrained from prioritising their recommendations, and rather limited it to one main suggestion: the establishment of a CEG Diversity and Inclusion Team. All information gathered by the ACC and their suggestions will serve as a starting point for the new team.

4.7 Short questionnaire about Research Integrity

The upcoming CEG Mid-term Research Evaluation needs to include a discussion about Research Integrity, including suggestions for improvement.

In the 2018 Review, the assessment committee wrote that *“all systems and procedures are in place, but we noticed in the interviews that this topic is not seen as very important in daily practice. No signs of problems were observed at this stage, but we encourage the Faculty to make this a regular point of attention and discussion”*.

In order to form a better picture of current practices across the faculty, we would appreciate whether the members of the MT could answer a few questions.

From the Netherlands Code of Conduct (Netherlands Code of Conduct for Research Integrity), adopted by TU Delft, Research Integrity is explained by the following principles:

1. Honesty
2. Scrupulousness
3. Transparency
4. Independence
5. Responsibility

In addition, the following issues are relevant for research integrity:

6. Data privacy rules
7. How to handle potential conflicts of interest

Questions:

1. In your opinion, which principle/topic of the above requires more attention and why
2. Would you suggest additional points of attention?
3. Is there in your department any training on research integrity for different career stages, and if so what type of training is it?
4. Is research integrity discussed in R&D meetings for scientific staff (post-doc and senior staff)?
5. Do you know whether all scientific staffs are informed about the TUD Code of Ethics and Integrity Roadmap (<http://integrity.tudelft.nl>)? If yes, how does it happen?
6. Any additional comment:



5. Human Resources Policy

5.1 Introduction

TU Delft has a strong human resource policy built on an important aspect of its mission:

“(…) We develop and enhance the expertise of tomorrow’s engineering leaders and educate professional, high-level and responsible engineers throughout their careers.”

This part of the mission covers all aspects of Human Resource policy:

- conduct world-class research by combining science, technology and design in a socially responsible manner and promote and disseminate the benefits of technology.
- develop and enhance the expertise of tomorrow’s technical leaders and train professional, high-quality engineers with integrity throughout their careers.
- help develop and offer technological, innovative solutions to societal problems through cooperation with leading national and international partners, while remaining firmly anchored in Delft.
- continue to improve our collective effectiveness, performance and organisational resilience through professionalism, cooperation and openness.

Connected values are as follows: diversity, integrity, respect for others, commitment, courage and trust.

HR focuses on the following aspects to contribute to the above-mentioned mission:

- recruit and retain ambitious and talented employees.
- stimulate and value talent development and sustainable employability of employees.
- offer employees a safe, challenging and meaningful work environment.
- organise efficient HR support .
- advise on organisational development.

In addition to what we do, also important is to consider how we do it: professionally, with commitment, openly, with impact and (above all) together.

Main tools in this process:

- recruitment processes have been improved, both in terms of processes as well as via introduction of new tools.
- development is strengthened, especially for new scientific staff; TU Delft offers a designated and in some ways tailor-made Personal Development Programme, along with carefully monitored career paths.
- instruments are provided, especially for temporary staff, to guide them to a new job shortly after termination of contracts, and opportunities are provided for older employees to make use of special arrangements prior to retirement.

CEG follows policy developed by the central HR Directorate of TU Delft ([Human Resources \(HR\) - Intranet](#)). Additional policy is added or tools are used only on a very limited basis, and only if necessary. In the following paragraphs, we will point out the major topics in this faculty policy, and we will focus on points of improvement.

5.2 Academic Career

5.2.1 Tenure track

In 2012, TU Delft implemented the tenure track system, in which new permanent academic staff start in a temporary position of 5 years before getting tenured, in which they must develop themselves based on transparent criteria. In recent years, several highly talented and motivated new staff members joined the CEG community. During the tenure track, the personal development plan is of utmost importance. In addition to developing their own fields of expertise, CEG expects new staff members to develop leadership traits, writing and presentation skills and, if applicable (since the plan is personal), other aspects in order to avoid becoming a solitary specialist and in order to encourage their connections to other colleagues. These traits are defined in the CEG criteria.

5.2.2 Development (leadership)

CEG aims to have a staff consisting of highly motivated top talent with multidisciplinary interests and experience, an application-orientated mindset, didactic qualities and broad competences in terms of networking, entrepreneurship, leadership, organisation and communication. This means that CEG is constantly working on staff development, to develop within academic ranks, in line with the tenure track system. Special attention is paid to developing personal and leadership skills.

Several programmes are offered, specifically aimed at the different target groups (assistant professors in tenure track, but also associate and full professors). In particular, for assistant professors, participation in this Personal Development Programme (PDP) is a prerequisite for taking steps in an academic career. For the tenured UDs and UHDs, the U(H)D programme has been developed as a follow-up for the PDP. In addition, for more senior or older staff members, much attention is paid to development, and this is an important part of the yearly R&D meeting. Departments reserve 1% of the gross salary budget for individual coaching and training in leadership development for external hires.

5.3 Well-being

Shortly before the pandemic, the TU Employee survey was held, also resulting in several issues to be addressed:

- workload being still higher than acceptable for employees.
- social safety.

In addition, the last year in particular was a difficult year due to the Covid-19 pandemic. Working from home can easily lead to losing connection and motivation and in many cases can lead to serious feelings of discomfort. This was especially the case for our PhD candidates coming from abroad. At faculty level, the dean provided motivating messages, stressing everyone to keep an eye on each other, along with several online meetings with a mix of inspiring speakers and more social activities. In several departments, buddy networks were started to try to keep PhD and/or MSc students connected, both being vulnerable groups.

5.3.1 Workload

In the employee survey, workload was regarded as higher than acceptable. Indeed, the pressure is high, especially for those staff members conducting research and involved in education. Influx of students has sharply risen, and the battle for research funding increased. That said, given the additional staff appointed through the so-called 'Wet Studievoorschot' financing, one might expect a better grade on workload; however, this was unfortunately not the case, perhaps because student numbers rose even more sharply in recent years. However, with the aforementioned influx of new assistant professors in the Van Rijn and Sector plan schemes and the start of a new financing program 'Wet Studievoorschot', CEG expects workload to decrease.

5.4 Social Safety, Inclusiveness And Diversity

The two words 'safety' and 'inclusiveness' are inextricably linked. CEG strives to have a safe working environment. Safety and inclusiveness cannot exist without diversity and affect the way we interact with each other. What do these themes mean in our administrative culture? What does safety look like when we are dealing with each other? CITG believes it is important to pay attention to this. The leadership programmes offered to academics pay attention to these themes. Specific training and workshops are offered to faculty management. Unfortunately, due to the coronavirus, planned training has been postponed to future dates that are yet to be determined.

That said, academic culture and spirits are good overall. In the Employee Monitor 2020, CEG has a positive score on inclusiveness and respect from supervisors. However, some (and 'some' is already too much) of our staff members report having experienced or heard of undesirable behaviour. CEG is determined to improve on this aspect, mainly by:

- taking measures in individual cases.
- starting discussions and a course to empower employees on this topic, as well as to create awareness with supervisors (a pilot on will launch around May 2021).
- encouraging an open door policy of supervisors, as well as training supervisors in how to act in cases of undesirable behaviour.
- encouraging employees to communicate with their supervisor or other bodies within TU Delft (confidential advisers, ombudsman, University social worker).
- looking carefully at social skills during selection procedures of supervisors/ management.

5.4.1 Diversity

As stated in the assessment report, diversity is a broad topic, of which one can think of in terms of age, cultural background, gender, nationality, social background, sexual orientation, disability or disciplinary background. All aspects are important, and CEG strives to be an open and inclusive community in which individual members can flourish. Topics related to academic culture will be addressed in a separate chapter, we will therefore focus on two main issues, also addressed in the assessment report:

- gender balance
- homegrown PhDs and staff

5.4.2 Gender and international balance

Especially in the more classical civil engineering domains, the number of female scientists was relatively low. A concern of the assessment committee was also the risk of female staff members getting into a position of isolation; thus, appointing new female staff to create a 'cohort' was advised. The committee also pointed at the extremely low number of female MT members. In the assessment period, many staff members could be appointed thanks to the Van Rijn and Sector plan schemes. Apart from that, CEG actively scouts for possible candidates in the Delft Technology Fellowship scheme.

The number of potential female scientists in the more classic fields in particular is comparatively low; thus, the search for female candidates for vacant positions was intensified. This was mainly done along four lines:

- carefully checking all job adds for attractiveness for potential female applicants and checking on gender-balanced use of words.
- asking vacancy holders to scout for female scientists in their networks, and asking female scientists in their network to scout.
- making one female scientist per selection committee mandatory in order to avoid male bias.
- starting the selection procedure only if 50% of the candidates on the shortlist were serious female candidates.

Also, 'Support for International Employees' is called in at an early stage. One of the most important aspects of 'Coming to Delft' is the support in finding a job for the accompanying partner. These combined measures resulted in a sharp increase in influx of female staff (11 of the 22 positions). This sharp increase of influx of female candidates, combined with the Personal Development Programme, which is also focussed on leadership skills, should lead to female MT members in the future.

Improving gender, especially in the higher ranks, is a major topic for the period to come. In total, CEG has 193 faculty members (assistant professors, including tenure trackers, along with associate professors and full professors), 25% of which are female. Of these 193 faculty members, CEG has 56 full professors (salaried), and among these 56 full professors, 11% are female.

Table 5

Faculty members (UD, UD-TT, UHD and full prof.)			Full prof.		
	#	%		#	%
total	193		total	56	
female	48	25	female	6	11

We need to carefully monitor possible issues that female and international colleagues might experience, work on a safe and pleasant atmosphere and be continually aware of potential male biases, of course in close cooperation with the faculty diversity officer, who has been appointed in May 2021.

5.4.3 Home grown staff and diversity in career

The assessment committee addressed the relatively high amount of home grown PhDs and staff members. This indeed could have risks for creating an inward-looking academic population. During the period 2012-2020, 58 UD tenure trackers were hired. Of that population, about 30% had no previous ties to CEG. In the recent recruitment of 22 new tenure trackers (2020 – now), the result was 33% home grown, with 66% from outside the TU Delft.

If regarded appropriately in terms of development, staff members (especially those with a longer CEG history as PhD, postdoc or researcher) are encouraged to spend a period abroad in order to broaden their horizon and enlarge their network. This can be facilitated through sabbaticals or maybe even better as an exchange.

Criteria for becoming assistant or associate professor in fact requires (nearly) full-time appointments. However, in several fields of expertise, part-time staff members are needed to strengthen the relation with the sector (companies, institutions), to incorporate knowledge from practice into education and to strengthen the relation between academic research and professional practice. To avoid loss of quality, CEG specified qualifications for part-time associate professors. This demand existed both at CEG and within the sector. Although this track is currently established, approximately 20 part-time associate professors have been appointed.

The academic career path has been expanded to include a career for UHD and full professor where the emphasis is on teaching (70% education- 30% research activities). As of 2020, more possibilities are created to differentiate within the performance criteria (education, research, valorisation and organisation/leadership) and to develop a more specialised educational career path. This path can be chosen in cases of exceptional educational achievements, like educational renewal, impact on educational programmes and so on.

5.5 Outlook

The labour market for scientific staff has also changed. TU Delft and CEG have a firm reputation both within the Netherlands and abroad, and we must compete in a difficult market where our primary employment conditions are unfortunately not always attractive compared to other companies and institutions searching for the same scarce talents. This means that we must professionalise our recruitment by following alumni in their development, constantly looking within and outside of networks for possible future co-workers and being supported by mature recruitment processes.

Related to this, in the coming period we will focus more on thinking about staff and development from a more strategic perspective, i.e., which goals we have set for the future and what impact those goals have on the profile of current or forthcoming vacancies. More strategic alliances can be established by appointing industrial fellows in addition to part-time associate professors. These fellows are role models from practice mainly involved in design and engineering education. Their appointment bridges gaps between academy and practice, bringing in more practical solutions to scientific challenges. Also, a new wrinkle in faculty beyond educational associate and full professor, in addition to the current performance criteria, is one way to look forward.



From concrete waste to concrete buildings

This picture accompanies a story about our research into recycling concrete demolition waste to high quality 100% circular raw materials that can immediately be used to produce new concrete. All stories of science of the department Engineering Structures can be found [here](#).

6. Engineering Structures

6.1 Introduction and mission

The department of Engineering Structures (ES) was formed in 2018 after the former Department of Structural Engineering (SE) was split into two departments, ES and 3MD. These two departments have common responsibility for the educational programmes and cooperate in joint acquisition of large multi-disciplinary projects.

The mission of our department is to provide engineering solutions for people and climate.

We do this by training the next generation of civil engineers and advancing engineering science. We focus on engineering structures that mitigate climate change and we reduce the footprint of current engineering practices. We develop new engineering solutions for (infra)structures to accommodate the needs of a growing world population and ongoing urbanization.

Within our department we work on four main themes:

1. Structures for energy transition
2. Recycling and naturally recyclable structures.
3. Infrastructure and transport for future-proof built environment
4. Enhancement of safety of structures and infrastructure by means of introduction of innovative types of construction materials and smart monitoring and testing of existing structures.

These themes are closely correlated with and significantly contribute to two major research themes our faculty is focusing on, namely, the Urbanisation and Transition to Renewable Energy Systems. Our department assures that such fundamental for the faculty disciplines as Mechanics of Solids and Structures, Physics of Materials and Transport Systems Science are maintained at the world class level. At the same time, the department strongly contributes to all the major cross departmental themes by focusing on data collection, monitoring, risk analysis, uncertainty propagation, numerical modelling and the use of smart materials at the full structural scale.

6.2 Recommendations of previous assessment and follow-up

The previous assessment resulted in a positive evaluation of the department with good scores. Suggestions for improvement provided by the evaluation committee have been carefully analysed and addressed as specified in table 6.

Table 6

Theme	Remark from previous assessment	Status and follow-up
Organization	With the reorganization into two new departments, it became clear that a small number of research fields requires closer attention. These areas should be strengthened if they are considered worthwhile keeping. We recommend that the (faculty) MT strongly supports the new department heads in this important task.	At the time of the previous assessment a few research directions within the ES department were relatively weak in terms of the research output and research funding. By means of forming smaller and more focused research groups and, simultaneously, introducing research teams that transcend traditional section boundaries, significant progress has been made in focusing the groups on the actions which are most likely to bring success and, at the same time, involving the somewhat weaker groups in the joint initiatives led by the strongest research groups within the department.
HR/people & community	SE is aware of the small proportion of female faculty. Recently hired tenure track professors reflect a more balanced ratio of 50/50, but it remains a critical point of attention as the cohort of female faculty members is far from critical mass.	Significant effort has been made in the direction of improvement of the gender balance in the ES department. We increased the percentage of women in the academic staff of the department from rather disastrous 10.2 % in 2018 (2.6 out of 25.3 fte) to still insufficient but significantly more appropriate 25.4% in 2021 (7.5 out of 29.5 fte).
	We want to emphasize to the MT and the Executive Board, although they seem aware of this, the critical role of SE and the importance of its sound combination of experimental, application oriented and foundational research with services for society. We are concerned that this combination might systematically lead to a slightly negative impact on H-indices, which may hurt external funding if such indices are over-emphasized and over-valued.	While we fully agree with the assessment by the committee, the ES department has nevertheless made significant effort in improving the classical indicators such as the H-indices of the academic staff during the last three years. This is being done in full understanding that the major strength of the department lies in the combination of fundamental and application-driven research, both strongly supported and often led by experiments, as excellently formulated by the committee. Thus, the improvement has been achieved not by means of paying less attention to any of the important components of our research but by making it a habit to publish newly obtained significant results of importance for the research community and the society as a whole.
	It can be challenging for SE to show evidence of its societal relevance to TU Delft and funding organizations as the common metrics used to measure success in research and valorization are not always optimally suited to SE's portfolio. We once again want to emphasize the critical national importance of the work done in SE with respect to safety and mobility (imagine the devastating impacts of large infrastructure failures) and we are concerned that this very important contribution may not be recognized and supported as deserved by the Central Board of the University.	The diversification of the funding sources in the Netherlands and long-awaited shift of the EU policy towards stronger support of sustainable economy and railway infrastructure helped the ES department to significantly improve its project portfolio in the past 3 years. Another significant improvement of the project portfolio is associated with a new for the department focus on the renewable energy, especially the offshore wind energy. The Sectorplan offers new opportunities for our department to attract funding from the government. Within the technical sciences, several focal points have been defined, of which Materials and environment, Multi-scale mechanics of structures, and Dynamics and monitoring of structures and infrastructural components have clear links with our research.
	We recommend that SE clearly formulates its research in terms of safety and security.	We clearly formulate our research in safety and security as part of our fourth main theme. To strengthen this theme, a new section <u>Mechanics and Physics of Structures</u> was established, that specifically focusses on condition monitoring: damage characterization, destructive and non-destructive testing, innovative and efficient monitoring methodologies, and residual life assessment. Within our department we established a Monitoring Community with members from multiple sections, that takes a multidisciplinary approach to the monitoring and safety of large infrastructure. This allows us to formulate new research questions in terms of safety and security.

Theme	Remark from previous assessment	Status and follow-up
HR/people & community	We furthermore recommend that SE develops more cohesion in its organizational structure and its research themes to further increase impact. For example, SE and TP should work closely together and built collaborative research programs to address the huge challenge society faces in renovating its existing infrastructure.	We established an alliance with Prorail, in which CITG is represented by scientific staff from both the ES and the T&P department. A new, TU Delft-wide, Railway Institute was founded in 2021. It is led by the representatives of the ES department and functions in close cooperation with members from different faculties and departments, including 3 departments of the CEG faculty, namely T&P, 3MD and GSE.
	We recommend that SE extends its networks to enlarge its impact. We are convinced that a stronger departmental research vision will be of great help. We further recommend that TP and SE use the Dutch Top sector Logistic. For SE, the top sector High Tech Materials might also be interesting. SE already produces spin off companies, a result we highly value.	We recognize the need to connect with networks, such as the top sectors. Therefore, we are active in the platform Infraquest and we are a partner of the joint research program GROW (50 Mln support from the industry). Many project proposals have been submitted by GROW to external funding bodies, of which several have been granted and are currently being executed within the ES department.

6.3 Research and innovation: Developments since last research evaluation

The department focuses its activities on four main themes all of which are strongly supported and often led by the experimental research conducted in our unique Stevin 2 laboratory. This laboratory serves both the ES department and the university as a whole by means of accommodating such unique machines as the hexapod for accelerated fatigue testing and a glass lab.

6.3.1 Structures for energy transition

Our ambition to drastically reduce CO₂ emission results in the need for a significant increase in electricity produced by renewable energy sources, with Offshore Wind being one of the key contributors in the foreseen energy mix. In the development of a wind park the installation of the wind turbines is a costly and time-consuming phase, while the installation-induced noise disturbs marine fauna. The ES department actively and volumiously contributes to the fundamental and application-driven research in the field of Offshore Wind. In the Gentle Driving of Piles (GDP) 1.0 project (Prof. Metrikine, RVO, TKI Wind at Sea), low-frequency axial and high-frequency torsional vibrations were combined for a novel and more efficient installation process, with less underwater noise, less damage of the monopile and improved extraction after use. In the DOT Fox project (Prof. Metrikine, RVO, topsector Energie) we are showcasing the feasibility of installing XXL wind turbines by means of a floating installation vessel, instead of bottom-fixed jack-up vessels only, which are reaching their operational capacity. The three-year SIMOX (Sustainable Installation of XXL Monopiles) project is part of the application-driven effort to develop, to the level of certification, an environmentally-friendly method of installation of the monopiles supporting the Offshore Wind Turbines. Within SIMOX, representatives of the ES department (Dr. Tsouvalas and Prof. Metrikine) are leading a large consortium with Deltares, TNO, offshore contractors Van Oord, Boskalis and Seaway7, DOT (Delft Offshore Turbine), equipment manufacturers Sif, IHC IQIP, CAPE Holland and GBM Works, Shell, RWE and Siemens Gamesa Renewable Energy. In a Demonstrator project (Dr. Pavlovic, NWO, Tree Composites B.V.) the commercial feasibility of the implementation of the wrapped composite joint as a component of a fatigue prone multi-membered structures is studied. The wrapped composite joint is a game changer in steel, fatigue prone structures. Multi-membered structures such as offshore wind structure currently have welded joints. The challenge for any multi-membered structure lies in the

economical design and manufacturing speed/capacity due to its unfavourable challenging welded joints. The Innovation of the Wrapped Composite joint replaces the traditional welding delivering a structure with higher fatigue resistance, reduced steel volume, increased lifetime and reduced price.

6.3.2 Recycling and naturally recyclable structures

In order to mitigate resource depletion and to reduce our footprint we need to transition to a circular economy. The use of biobased and/or reusable materials and development of novel recycling technologies are key to this transition. In the TERRE project (Dr. Van der Kuilen, EU) the interaction between wood, soil particles, air and water and its effect on mechanical behaviour is addressed. In addition, bio-chemical processes at the interface between atmosphere and timber or earthen construction materials were considered. We participated in two EU projects focusing on the recycling of End-of-Life building materials. One of them was the ICEBERG (Dr. DiMaio, EU) project, in which the TU Delft developed a biofuel based thermal attrition mobile unit for the production of higher quality recycled concrete sands. In the VEEP (Dr. DiMaio, EU) project, a heating air classification system which uses a combination of heating and grinding to produce clean sand and hardened cement paste from the problematic crushed concrete fines was developed. In the Vivimag project (Ir. Berkhout, EU), a new separation process to recover the iron phosphorus mineral vivianite from digested sewage sludge was developed. This process will help to recycle phosphorus, which is a critical resource for food production but currently used in a linear fashion, leading to waste production and eutrophication.

6.3.3 Infrastructure and transport for future-proof built environment

Research in the ES department on infrastructure and transport includes research on bridge engineering, pavement engineering and railway engineering. For railway engineering, we now have an alliance with ProRail, which is responsible for the maintenance and development of the Dutch railway tracks. In railway systems, rolling contact fatigue is a major problem, leading to high maintenance costs and dangerous cracking. In the Maxlife project (Prof. Zili Li, NWO), rolling contact fatigue was reproduced in controlled laboratory tests for a range of rail materials on our vehicle-track interaction test rig. In the In2track2 project (Prof. Zili Li, EU), friction management for the wheel/rail-interface was investigated, including simulations and laboratory characterization of friction modifiers/lubricants. The effects on rolling contact fatigue, wear, noise and vibration were assessed. For the construction of concrete structures, we investigate new hybrid concrete materials with a focus on the interface between these different types of concrete and how to upscale its application (NWO Veni dr. Lukovic). Research on pavement engineering focusses on the characterization of pavement materials at various scales, using both experiments and numerical models, and the design and maintenance of various types of pavements. Our research is mainly oriented towards the aging and the healing response of asphalt mixtures, their rejuvenation and recycling without compromising performance (NWO Veni dr. Varveri). Also, research is performed on soil stabilization via various techniques and on the design, analysis and construction of concrete pavements. The experimental facilities cover the full scale range, from chemical and nano scale techniques like infra-red spectrometry (FTIR), atomic force microscopy (AFM) and nano CT scans. Our powerful parallel computing facilities enable us to develop and apply advanced numerical models for research at all these levels of material response. We have a LINTRACK facility which enables us to conduct full scale accelerated pavement tests. Unfortunately, it was temporarily closed but will be operational soon. We receive funding from (Rijkswaterstaat, part of the Ministry of Infrastructure and Water Management), construction/engineering companies such as Boskalis and provinces and municipalities.

6.3.4 Enhancement of safety of structures and infrastructure by means of introduction of innovative types of construction materials and smart monitoring and testing of existing structures.

Several types of structures require continuous monitoring to ensure their safety. Monitoring of biobased structures is in many cases related to moisture content measurements, to check and prevent decay in properties of load-bearing elements. We have projects with the municipality of Amsterdam (Prof. van der Kuilen), to investigate the structural integrity and the load-bearing capacity of the wooden poles on which the city is built, therefore contributing to the preservation and maintenance of our cultural heritage and one of the most densely populated areas of the Netherlands. The continuous monitoring of concrete bridges is necessary to ensure their safety and prevent costly maintenance. Our research is focussed on non-destructive techniques such as acoustic emission for damage detection (Dr. Yang), and on assessing and developing guidelines for proof loading of existing structures (Dr. Lantsoght). Our research also includes transformation the existing concrete bridges into smart structures by embedding sensors such as optical fibres and smart aggregates (wave based transducers). With that, we are able to track the possible degradation of the existing structures and give an early warning to the asset owners. The majority of the concrete bridges and tunnels in the infrastructural network of the Netherlands was constructed in 1950's and 1960's. They were designed according to over simplified design regulations and less traffic load than nowadays. In addition, the original design information of many of the existing bridges are missing already. Together with Rijkswaterstaat, we work on reevaluating the safety of the existing concrete bridges and tunnels by: developing advanced theoretical and nonlinear FEM models in combination with experimental validation (Dr. Yang), using reliability based model update (Dr. Lantsoght). The output of these research will help the owners of the concrete bridges and tunnels to optimize their maintenance strategy and reduce unnecessary interventions such as repair and/or renovation.

6.3.5 People and community

We aligned the annual R&D (Results & Development) meetings with CDC (Career Development Council) expectations and recommendations. R&D and VLC were aligned by organizing departmental pre-assessment by the ES board. Before the R&D meetings take place, the ES board has a preview in which exceptional cases (both over- and underperforming) are discussed in order to harmonize the R&D cycle. Additionally, any candidate for promotion (assistant prof. to associate prof.) is nowadays first discussed by the ES board before being recommended for promotion to the CDC. By involving the ES board in the calibration of both R&D and CDC, better alignment is achieved between them. By aligning R&D meetings and CDC, more transparency is created regarding guidance, training and promotion. Before recommending someone to the CDC for promotion, organizational activities and recognition as a team player are explicitly considered. We are using the position paper "Room for everyone's talent" as inspiration as how to reward these initiatives. The plans formulated in each R&D cycle are closely related to the main direction of research, teaching and organization of each member of the department. Coherence with the faculty mission and plans is achieved by correlating the plans with the agreed at the faculty level educational tasks and focal research directions. We have been actively recruiting female faculty members. As a result, we were able to hire five female academic colleagues in the last two years. The ES board includes 4 (out of 10) young assistant/associate profs. These include three section leaders and the chair of our Young MT, which is composed of the assistant professors and tenure trackers representing each research group of the department. The Young MT was established in 2018 and proved to be a great success leading to a much stronger cooperation between the research groups in the department and a continuous flow of new impressive initiatives, which allowed to use the broad spectrum of knowledge present in the department in a more coherent and focused way.

6.4 Outlook

In order to define concrete actions for the next years, we performed a SWOT analysis. Based on the SWOT and a confrontation matrix, we defined 9 key actions specific for our department that will allow us to leverage our strengths and mitigate our weaknesses in order to be better prepared for external developments.

1. Invest in lab equipment to contribute to societal challenges

Our lab is a unique facility. In order to capitalize on the opportunities that will arise from societal challenges, such as the energy transition and the circular economy, we must invest now in lab equipment that will position our department as the preferred partner for new research projects.

2. Include labwork in education

Our lab provides us with the unique possibility to integrate labwork in the educational program. This way, we will attract the brightest students and continue to train the next generation of civil engineers.

3. Empower and support scientific staff to make the educational redesign a success

Our young scientific staff is very talented and has the potential to successfully complete the educational redesign process. We should empower and support them in every way we can to ensure the training of the next generation of engineers for years to come.

4. Use the lab facilities as unique selling point to attract long term research funding from our industry contacts to reduce our workload

In order to reduce our workload, we need to employ more (permanent) (teaching) staff. However, the first money stream is limited so we need to ensure sufficient (long term) funding from the third money stream. We will use our excellent contacts with industry to engage in mutually beneficial cooperation agreements that will provide us with long term funding.

5. Encourage cooperation to make the educational redesign a success

The educational redesign process transcends section and department boundaries. In order to channel our precious energy towards a result that benefits the entire faculty and not waste it on internal competition, we need to encourage cooperation. We will align our communication and the way we reward individuals to achieve this.

6. Invest in our grant application process in order to contribute to societal challenges

An increasing amount of 2nd money stream funding is available for research consortia that address societal challenges. In order to successfully obtain this funding, consortia have to be formed and research questions formulated in order to generate societal impact. In order to increase our chances of success, we will encourage cooperation between sections and departments, encourage consortia forming and reserve funding to hire professional grant writers

7. Encourage cooperation within the department to reduce the workload

In a large department like ours, redundancies in expertise inevitably occur. We will encourage people to think outside their own section and seek cooperation to create synergies and reduce the workload

8. Invest in our Health, Safety and Environment (HSE) organization to improve safety and minimize the risk of accidents

Operating our lab is not without risk and safety has our highest priority. Safety is dependent on a clear organization with clear responsibilities and mandates. We will work with all stakeholders to improve our HSE organization in order to prevent accidents from happening.

9. Increase (entry level) of training and English proficiency of PhD students to increase lab safety and to reduce workload

The (entry level) of training of new PhD students joining our department is not always sufficient to work safely in the lab, and requires above average supervision time, which negatively affects the workload. In order to improve the safety and reduce the workload, we will uphold high standards regarding prior training and English proficiency when recruiting/selecting new PhD students. In certain cases this means we will not take on self-funded PhD students.

6.4.1 Research & Innovation

Below we outline new research directions within our departments related to the four main themes.

1. Structures for energy transition

The transition to renewable energy requires many engineering solutions. We will work on two new Gentle Driving of Piles projects, which will bring results of the successful GDP1.0 project closer to the large-scale industrial application. These GDP1.2 and GDP2.0 projects (Prof. Metrikine, RVO) are an important step towards the final goal of the whole GDP projects chain which aims at creating a commercial GDP product. In the new, just granted, Wrapped Composite Joints for Next Generation Offshore wind support structures (Wrapnode) project (Dr. Pavlovic, RVO), the ability of composite joints to replace traditionally welded joints in offshore wind support structures will be investigated, which may lead to a cost reduction to offshore wind developers of 25%-40% for the supporting structures and a carbon footprint reduction of 30%-40%. We are currently exploring future research avenues such as Floating windmills and Hydrogen@Sea.

2. Recycling and naturally recyclable structures

As the demand of precious rare metals will increase the coming decades, recycling will increasingly important. In the recently granted PEACOC project (Dr. DiMaio, EU), improved technology for recycling of Platinum Group Metals as well as Gold and Silver from Printed Circuit Boards and Spent catalysts will be developed. We are part of a large European consortium that will develop improved Lithium recycling technology, which will be essential to keep up with the growing demand of Lithium for batteries for electric cars and other equipment. We recently hired a new tenure track assistant professor, Dr. (Ms.) Wenjun Cao, who will develop the fundamental understanding of circularity in the design, construction, operation, maintenance and repair cycle of civil infrastructure.

3. Infrastructure and transport for future-proof built environment

In the coming years, we expect several large-scale projects on various types of infrastructure for transport and mobility. In a large project with Prorail on Embankment Stability (15 M€, of which 4-5 M€ for TUD) TU Delft and Deltares will participate in an applied research program to develop and implement new methods and knowledge to approach the actual safety level of embankments, enabling ProRail to safely increase railway traffic on soft soil embankments. We are anticipating a similarly large project (20M€ of which 5-7 to TUD) on Vibrations from Railways. A large-scale long term research program with on Knowledge Based Pavement Engineering funded by Rijkswaterstaat is close to being finalized. This program specifically addresses pavement engineering challenges, with a focus on material properties. In our NWA (Dutch Research Agenda) "Moonshot" proposal, we will address several technical and societal questions regarding the development of the Hyperloop (dr. Van Dalen, NWA). If granted, we aim to achieve several breakthroughs that will bring the Hyperloop several steps closer to reality.

4. Enhancement of safety of structures and infrastructure by means of continuous monitoring and smart AI algorithms

Several members of our scientific staff, including dr. (Ms.) Alice Cicirello and dr. Alessandro Cabboi, started in the last years and are working to establish their research lines. To strengthen this theme, a new section Mechanics and Physics of Structures was established, that specifically focusses on condition monitoring: damage characterization, destructive and non-destructive testing, innovative and efficient monitoring methodologies, and residual life assessment. Within our department we established a Monitoring Community with members from multiple sections, that takes a multidisciplinary approach to the monitoring and safety of large infrastructure. This allows us to formulate new research questions in terms of safety and security. A new project will start with Witteveen+Bos and Rijkswaterstaat on the monitoring of bridges (dr. Eliz-Mari Lourens). We recently hired a new tenure track researcher (dr. Hongrui Wang) on the topic of Artificial Intelligence. He will work with staff from different sections to integrate AI with their research and specifically focus on AI-based digital modelling and design of engineering structures, AI-based asset management optimization, and AI-based structural health monitoring.

6.4.2 People and community

We will align our (HR) policies and R&O criteria in such a way to support our key actions as defined by our SWOT analysis. Specifically we will encourage and reward teamwork and cooperation. This includes working together with others on the educational redesign, and writing grant proposals together with others within and outside our department. We will encourage scientific staff to grow their network and become a member of external committees and councils, related to the topsectoren and public private partnership. Despite the high workload, scientific staff should feel permitted and empowered to engage in strategic activities that may benefit them in the long term.

Counting Grains of Sand to understand coastal dunes

This picture accompanies a story about our research into coastal engineering and natural ways to strengthen our coastline. All stories of science of the department Hydraulic Engineering are available online [here](#).



7. Hydraulic Engineering

7.1 Vision and mission

The mission of the Hydraulic Engineering department is to educate world-leading hydraulic engineers, train academic scientists and carry out world-class research. The Hydraulic Engineering department aims at thorough understanding of relevant processes (e.g. hydraulics and morphology) in rivers, coasts, estuaries and seas. It also focusses on the engineering of and research on man-made interventions in support of safe and sustainable development of urbanised deltas and water systems, and the development of renewable energy in the marine environment. Our research and education agenda is driven by societal needs to design, engineer and manage human interventions in the natural environment, for purposes such as flood safety, flood resilience, navigation, freshwater supply, energy generation and supply, nature development and recreation.

To maintain our position as one of the world-leading departments in this field, we carry out ground breaking fundamental and applied research. To do so we use our extensive global network for application- inspired, collaborative research with academia, research institutes and practitioners. This requires continuous efforts to innovate and advance research and education. The approach of combining the challenges from practice with systematic scientific investigation of the underlying physical processes and functioning of engineered systems has been very successful. This has resulted in productive and innovative research inspired by both natural processes and engineering applications, as for example reflected in the “Building with Nature” concept. This is achieved through a synergistic combination of experiments in the laboratory, field observations and numerical modelling.

The hydraulic engineering research program and educational activities focus on the following key societal challenges identified for our faculty: climate change, the transition to renewable energy systems and enabling of safe and sustainable urbanisation and infrastructure in delta areas.

The department has defined the following four key themes: 1) dynamics of marine and inland water systems; 2) sustainable infrastructure and nature-based solutions (NBS); 3) climate adaptation and flood-risk management; and 4) renewable energy in the marine environment. These are directly linked to the core faculty disciplines (particularly fluid and sediment dynamics), societal challenges and cross department methods and technologies, as shown in Figure 14.

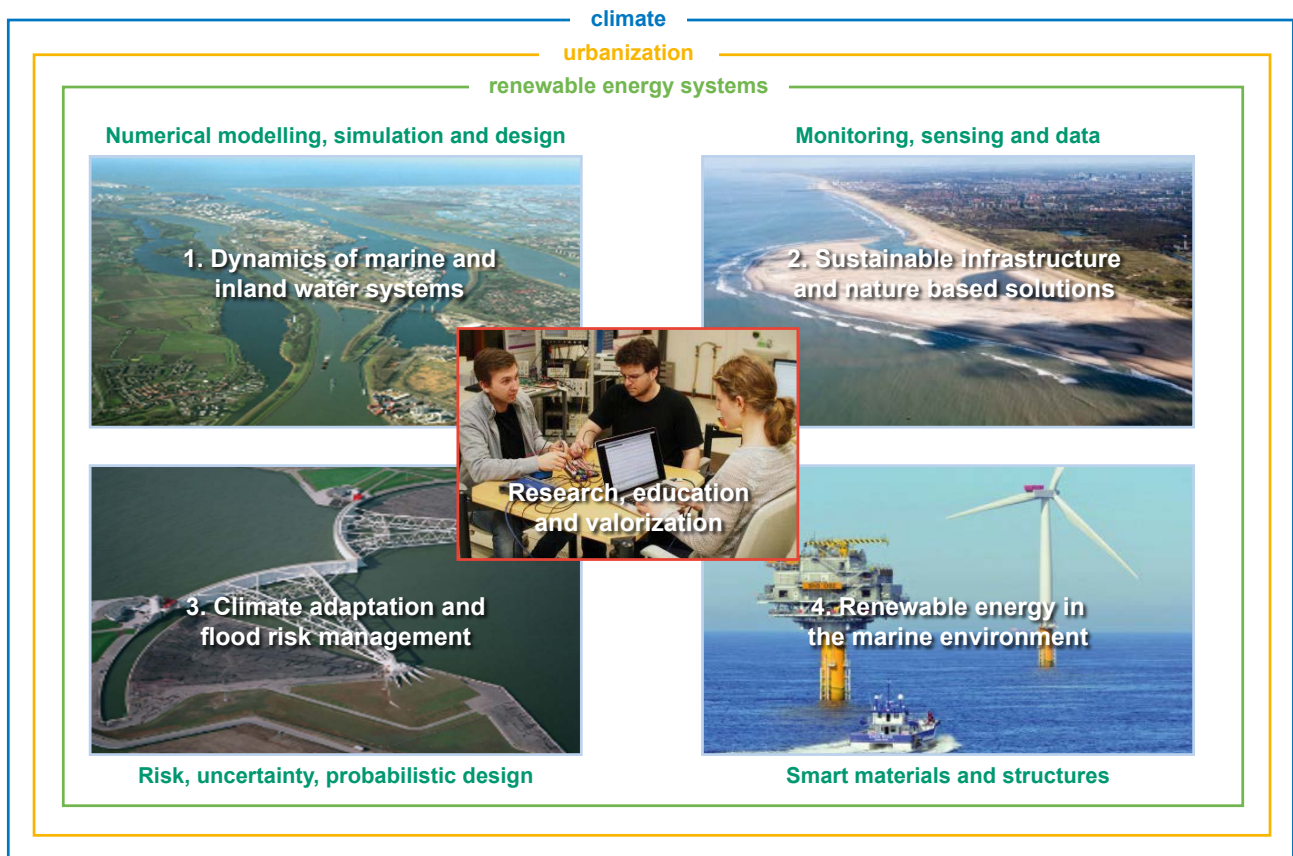


Figure 14: the four focal themes of hydraulic engineering embedded in the most related societal challenges with cross departmental methods and technologies for the faculty (in green). Source: Cape Holland

7.2 Recommendations of previous assessment and follow-up

The previous assessment resulted in a very positive evaluation of the department with high scores “excellent (1)” on all three indicators: research quality, relevance to society and viability. The assessment committee provided feedback and suggestions in four main areas. In the table below, we provide a summary of the developments, actions and future outlook for these four areas.

Theme	Remark from previous assessment	Status and follow-up
Physical lab facilities	“reductions in physical laboratory space and the MOU with Deltares should be carefully considered.” “keeping and evolving in-house laboratory facilities with state-of-the-art tools will be critical for the future”	<ul style="list-style-type: none"> • Lab use has been increased, in total ~20 projects (MSc, PhD) per year for innovative experimental research, e.g. dynamic response of gates under wave loads, sea ice-loading on structures. • Development of new in-house laboratory space (cold rooms) for work with sea and lake ice. • Innovative measurement techniques developed, e.g. embedded motion sensors in rocks, laser scanners for bathymetry, optical sensors for fine sediments and future investment made in facilities, e.g. a second wave paddle. • Lab organisation strengthened: dr. Bas Hofland became lab head, academic staff involved in lab committee. New (young) highly-skilled technicians with complementary skills (e.g. electronics, mechanics) have been hired and trained, to support lab and field work. • Collaboration with Deltares strengthened: prof. van Gent (lab director at Deltares) became part-time professor at TUD. Joint use of Deltares facilities as part of TUD research, e.g. use of large delta flume for testing trees and dikes with vegetation, and the wave basin for tests on the stability of rock on mild slopes. • Recently, it has been decided to make additional investments in the lab facilities.

Theme	Remark from previous assessment	Status and follow-up
Staffing of ports and waterways	"the ports and waterways section should be staffed with full-time senior faculty"	<ul style="list-style-type: none"> Mark van Koningsveld has been appointed in 2018 as a full professor in ports and waterways. With a new full-time tenure tracker to be hired early 2021 the group consists of a (part-time) full professor, a full-time lecturer and tenure tracker, several part-timers representing government, research institutes and industry and five PhDs. the group focuses on areas (big data, computer programming) which are important for the faculty, the group is also developing new teaching materials and support materials (online repository of data and codes).
Computational facilities	<i>"given its current leadership position in developing computational models larger dedicated systems would be appropriate and more necessary in the future... (and) are a key future investment in carrying on the department's tradition of developing coastal ocean processes software tools."</i>	<ul style="list-style-type: none"> We agree with and have taken steps to increase our computational capacity accordingly, including an extension of the in-house high performance computing (HPC), and an arrangement with SurfSara for small projects. Ties to DCSE strengthened (TU Delft Institute for Computational Science and Engineering), HE has joined effort to create a HPC cluster facility with an anticipated 30000 cores. We have also created a department committee to prepare a plan for future needs for computational capacity. This group will deliver a future strategy before the summer of 2021.
SDGs	"We are convinced that HE can enlarge its impact on the SDG even more by integrating other aspects in its research, such as agri and food, circular thinking, finance concepts and use of big data, artificial intelligence and social media."	<ul style="list-style-type: none"> An interdisciplinary approach is indeed necessary to achieve impact in society. Core HE staff has embraced the topics of big data and AI (van Koningsveld, Aguilar-López, Lourens) and ecology (Herman, van Weesenbeeck). Other collaborations are shaped through faculty themes, projects and networks. One example is the European innovation project BRIGAD that focussed on enhancing climate adaptation innovations, including financial and social aspects. Another example is the multidisciplinary project SALTISolutions (see below). HE senior staff are active in networks that focus on achieving impact through interdisciplinary collaboration, for example the DIMI network (Deltas, Infrastructure & Mobility) at TUD, and the "Delta Futures Lab" focussing on multidisciplinary education. Moreover, the department aims to play a leading role in the Delta Convergence Initiative together with Erasmus University, which is shaping the future knowledge for sustainable delta areas through interdisciplinary collaboration.

7.3 Research and innovation: Developments since last research evaluation

Theme 1: Marine and inland waters

Global changes in climate, urbanisation and land use affect the complete water system, starting from river systems through ports, estuaries and deltas to coastal seas and deep oceans. Changes in one water body affect the other water bodies through non-linear coupling in overlapping transition zones affecting surface waves, (fine) sediment fluxes, salinity, temperature, river flow, tides and sea level, thereby shaping our rivers and coasts. Specific attention is given to the interaction of these processes with man-made structures and other interventions, while also their effects on pollutant and plastic transport, ecology, navigability and coastal safety are addressed further supported with new academic hires in these fields (Van de Bremer and Stancanelli).

Since the last research assessment, several new research projects have been initiated and executed to further our understanding of the complete water system. This starts at oceanic scales to understand and predict the changes in sea level at global and regional scales (VIDI Katsman, Versatile Hydrodynamics), to understand and mitigate salt intrusion in our deltas (SALTISolutions). This latter is a large project led by HE, granted as part of the NWO perspective programme and it focuses on safeguarding freshwater supply through a virtual model of the Rhine-Meuse delta.

At regional scales using a global-to-local downscaling modelling framework the stability of coastal (eco-)systems in the presence of climate change can be assessed (SCENES Part

B) allowing mitigation measures to be designed in an efficient way to maintain or promote habitats and associated ecosystem services including coastal safety. These include bamboo structures to restore mangrove forests (Biomanco, MuMaCo), re-use of dredged sediments to promote the growth of salt marshes (Mudmotor), large-scale nourishments at ebb-tidal deltas (SEAWAD) and tidal flats (EMERGO) to accommodate relative sea level rise, but also engineering solutions related to coastal safety and shipping. For the latter, new dredging techniques (WID) and fibre-optic based measurements are being developed as part of MUDNET (<https://www.tudelft.nl/mudnet>). Going upriver channel bed erosion caused by past channelisation measures hinders navigation severely, expected channel response to climate change is assessed, and mitigation measures and new modelling techniques are being developed (Rivers2Morrow, RiverCare, Water2015) including the use of environmental DNA (eDNA) for the assessment of river biodiversity at reach to catchment scale (Stancanelli). All research is supported by both field and laboratory facilities that have been extended and improved with new instruments and state-of-the-art numerical models (including in-house developed SWAN, SWASH and H2Ocean models for the prediction of waves, flows and tsunamis).



Theme 1: Biomanco project – restoring mangrove coastlines, winner of International Flood & Coast Excellence Award 2020



Theme 2: Duneforce project, understanding evolvement of coastal dunes.



Theme 3: Satellite and physics-based monitoring of short-term deformation of dikes.



Theme 4: “Gentle” driving of piles for offshore wind turbines to reduce underwater noise.

Theme 2: Sustainable infrastructure and nature-based solutions

Every strategic agenda (World Bank, UNDP, EU, national policies) presently calls for development and implementation of Nature-Based Solutions (NBS) to realise climate-resilient infrastructure. Scientific knowledge is commonly considered a key factor to enable evidence-based design of such infrastructure. NBS have inspired a paradigm shift in hydraulic engineering, as they fulfil their prime technological requirements along with a variety of additional benefits for nature, society and economy.

Since the last research assessment, the department has consolidated its leading position in research topics related to NBS. The underlying physical processes have been studied in the lab and the field. Examples include dune erosion (Realdune and Reflex) wave

attenuation by willow trees (WOODY, Hofland) as well as effects of natural foreshores under design storm conditions on waves (Living dikes) and breach growth in a dike (Living Lab Hedwige Polder). Also, the department develops innovative monitoring technology based on the use of laser, drone-based video and global satellite imagery.

A series of large-scale sandy interventions in coastal, lake and mixed-energy environments has inspired several projects to study the dynamics of NBS in the real world. These include studies on various dune sites (PRO-COAST and Duneforce), the Houtribdijk (LakeSIDE) and the Prins Hendrik Zanddijk (EURECCA). The potential for upscaling of such solutions in the context of accelerated sea level rise is explored as part of the C-SCAPE project. Only recently, the department started research into the use of NBS for the mitigation of salt intrusion in estuarine and port environments as part of SALTISolutions.

Representation in strategic advisory boards (Deltaprogram), review panels and partnerships (EcoShape) forms an important driver for this type of research. International collaborations with high-profile partners (Hohai University China, Flinders University Australia, US Army Corps of Engineers, Oregon State University USA, KAUST Saudi Arabia, Plymouth University UK, dual PhD programme with SKLEC and Qinghua University, and others) add to our visibility. With the recent hiring of new academic staff in the field of Emerging technologies for NBS (Antolinez), marine ecology (Van Wesenbeeck) and coastal structures (Van Gent) departments aims to further strengthen its position in this field.

Theme 3: Climate adaptation² and flood-risk management

In the Netherlands and around the world, there is an increasing attention paid to climate adaptation and flood-risk reduction. Since the last research evaluation, the capacity in this thematic field has extended through hiring two new tenure trackers - also affiliated with the 4TU Resilience engineering programme - in the field of innovative monitoring (Aguilar Lopez) and flood risk and climate change (Elisa Ragno). Cross links with other departments within the faculty have been strengthened, e.g. through a successful joint PhD research on satellite monitoring of dikes with the remote sensing group at out faculty, and with the TPM faculty to develop complex portfolios of flood-risk reduction interventions³.

There is a continued involvement in Dutch flood-risk management and delta planning through representation in advisory boards (e.g. ENW) and review panels (e.g. Delta programme). A core focus remains the reliability of defences and development of smart solutions. A large research program in this field (All Risk, NWO perspective) is led by the department (prof. Kok), which at the moment is in its final phase. New contract research on future reliability of storm surge barriers (funded by Rijkswaterstaat) and reliability of rock groynes (funded by the German BAW) is also starting this year. The group has played a leading role in investigating a recent collapse of quay wall in the centre of Amsterdam.

The EU project BRIGAD was led by the department and focussed on innovative solutions for climate adaptation and was finalised at the end of 2020. Internationally, the group remains involved in research by design for coastal protection in Texas, and new work on coastal adaptation – also through NBS – for Bangladesh and Mozambique for the Worldbank. A recently finished programme focussing on Shanghai (with Chinese and British partners) has shown a stronger integration of flood risk and climate modelling.

² The theme has been relabelled from “climate and ...” to “climate adaptation ...” as the broader theme of climate change is incorporated in the other themes as well, e.g. climate effects on oceans in Theme 1.

³ This work has won the best paper award for the journal of flood risk management for the paper “Evaluation of flood risk reduction strategies through combinations of interventions” by Van Berchum et al. (2020).

Theme 4: Renewable energy in marine environment⁴

Affordable and clean energy remains one of the crucial global Sustainable Development Goals, and a significant contribution to marine energies is foreseen both in Europe and worldwide. For the Netherlands and Dutch offshore industry, the development of offshore wind and ocean energy remain of particular interest, and have been included in the National and European Energy and Climate Plans.

Since the last research assessment, the department has consolidated its position in research on specific topics related to offshore wind such as the prediction and mitigation of underwater noise due to pile installation, the interaction between sea ice and wind turbine foundations (SHIVER), uncertainty reduction in offshore wind systems by smart monitoring of loads and damage (EUROS) and performance optimisation of low-head tidal turbines (Labeur).

Key projects starting during the last three years have focussed on Gentle Driving of Piles during installation (RVO, led by Metrikine), the SHIVER project (RVO) where dynamic ice-structure interaction for offshore wind turbines is addressed through the development of new cold room laboratory facilities at the faculty, and the EUROS project, Excellence in Uncertainty Reduction of Offshore Wind Systems (funded by NWO). The department has further been involved in the development from concept to full-scale installation and decommissioning of the slip-joint connection as an alternative to grouted or bolted connections for offshore wind turbines (RVO). Recent key EU projects for the department are the ALPHEUS project (led by HE) which investigates low-head pumped hydro energy storage and the VALID project which focuses on development of hybrid accelerating testing of wave converters.

Our ambition to grow in the field of ocean energy has recently gained momentum with the hiring of two new assistant professors working on fundamental fluid-structure interaction (Colomés Gene) and fluid-structure interaction with specific emphasis on marine energies (Lavidas). Links with other faculties have been established e.g., through a joint PhD project on development of a gyroscopically enhanced wave energy converter.

The four themes have their own focus, but are also combined in **crosscutting projects** where relevant in order to tackle the broader issues. Examples are the BE SAFE project that focussed on NBS for flood-risk reduction (Theme 2 and 3), the Biomanco and MuMaCo projects that addresses the physical understanding (Theme 1) and coastal protection (Theme 2 and 3) for mangrove forests, LakeSIDE Houtribdijk and Living Lab Hedwige Polder to innovative coastal management (Themes 2 and 3), SALTISolutions developing NBS to ensure fresh water supply under climate change (Themes 1,2 and3) and C-SCAPE developing NBS for coastal safety under climate change (Themes 1, 2 and 3).

People and community

- The department has employed one new part-time full professor and six new assistant / associate professors between 2019 and 2020. Two of them are replacements of leaving staff, while the others are an expansion of our department - particularly due to the sector plan funds. Diversity is a key focus in the recruitment processes. Three female tenure trackers have joined recently (Ragno, Van Wesenbeeck, Stancanelli) and the staff has become more international. Diversity has also been strengthened in other ways: representation in the department board, and recently a very large grant has been awarded to SALTISolutions project with a female PI (Pietrzak)
- Department management has been renewed, and regular staff meetings have been introduced which also serve as a platform for tenure trackers to provide inputs on developments and policy. Two associate professors are involved in the department board. Many staff members of HE play a leading role in faculty committees and developments, such as the board of examiners and new MSc programme.

⁴ <https://www.tudelft.nl/kennisvalorisatie/ontwikkeling-innovatie/tu-delft-offshore-renewables>

- HE has invested a significant amount of time and effort in dialogue within the department and with the VLC and faculty about the tenure track career policy. Tenure trackers have been involved in this process and have made suggestions to the VLC and faculty management to ensure a more balanced career development.
- The department has developed an action plan for the implementation of measures to reduce the educational workload across the group – as excess workload is still felt in specific areas. The new curriculum development consumes lots of (research) time and energy. There is continuous attention for the distribution of general education tasks, distribution of the BSc thesis is improved, participation to MSc committees is streamlined, transparent arrangements are made for PhD student involvement in our courses and a system of more strict selection of international students has been implemented. All of this is with the goal of a better balance between education, research and valorisation.
- Special attention has been paid to improving the conditions for PhDs and reducing PhD duration. Several actions have been implemented: PhDs are always supervised by multiple staff members, education activities of PhDs are recorded and managed. There has been special attention, and some contract extensions for PhD's severely affected by Covid-related delays. A 13-member working group with representation of PhDs and staff has developed best practices for minimising PhD delay which are now being implemented.
- The department continues to work on a professional and pleasant working environment, by encouraging team work, constructive feedback and an open atmosphere to discuss workload and well-being – especially under Covid circumstances. The altered circumstances, collaboration and tasks have a major impact on the way of working and well-being, and continuous attention is needed.

7.4 Outlook

7.4.1 Themes

As can be seen from the ongoing projects, future developments in this research theme of **marine and inland waters** are becoming ever more multidisciplinary for which we are well positioned to take a leading role in given our expertise in hydraulic and sedimentary processes at all scales. This includes the use of environmental DNA (eDNA) for the assessment of river biodiversity at reach to catchment scale (Stancanelli), the recently-started SALT project to mitigate salt intrusion in urbanised deltas to keep our fresh water needed for agriculture, drinking water, nature and industry. The continued development of the re-use of dredged sediment, in the framework of circular economy and turning waste into value in close collaboration with partners in MUDNET. The building of a high-resolution and system-wide monitoring network for the Rhine-Meuse delta as part of Danubius-RI project, dedicated to sediment and sediment dynamics in close collaboration with Rijkswaterstaat and the Ministry of Infrastructure and Water Management. In NKWK, governmental organisations, universities and knowledge institutes and consultants cooperate to achieve a climate-robust and resilient Dutch delta.

The second theme of **sustainable infrastructure and NBS** will gain importance in the years to come. Besides ongoing investigation of key bio-physical processes, research will be extended into integral evaluation frameworks (e.g. ecosystem services) and long-term adaptation pathways and tipping points. Research on hybrid solutions will provide answers for situations where nature-based approaches alone no longer work. High-resolution measurement sites and living labs (e.g. Ameland and Hedwige polder) based on the combined collection of in-situ, remotely-sensed and model-predicted data will be developed, both for the coast (ICON Coastline Observatories) and the Rhine/Meuse delta (Danubius). The latter offers unique opportunities for multidisciplinary research on eco-morphological processes and provides the test bed for new data-assimilation algorithms

for the now-casting (i.e. forecasting on very short term) of water systems. Building on the lessons learned from real-world projects in the Netherlands, we aim to contribute to the international uptake of NBS through strategic collaborations with partnerships across the globe.

The third theme of **climate adaptation and flood-risk management** will become even more important in the Netherlands and abroad. There is the ambition to take lead in setting up a “research by design” programme to show how adaptation of Dutch and international deltas can take place in view of sea level rise. Other important topics for the future will be the integration of NBS in the flood-risk management framework (with Theme 2), and technological developments such as new types of storm surge barriers and smart levees (including sensing, monitoring and artificial intelligence methods). Members of HE aim to take a leading role in large multidisciplinary initiatives. For example, Jonkman is involved in the new Pandemics and Disaster Preparedness Centre (PDPC) with Erasmus MC.

Within Theme 4 (**Renewable energy in marine environment**), the focus for offshore wind will be on XXL wind turbines (>13 MW). The main topics will be alternative foundation concepts for offshore wind piles and sustainable installation of XXL piles – for which the first project (SIMOX) has recently been granted by RVO to the department. We aim to develop integrated solutions for the Blue Economy and the water-food-energy nexus. Due to higher available energy density resources, less social opposition, and clear national and EU political commitments, exploration of offshore and marine energies will be of scientific interest. We have the ambition to create integrated solutions for marine and offshore energies to accelerate the energy transition. Examples of topics of key interest are the development of wave energy arrays for power production and multi-use of space at offshore wind parks for energy harvesting and aquaculture.

In achieving our ambitions and research plans, we foresee that utilising and expanding existing collaborations within the faculty and university are crucial. Some key examples are collaborations with the water management department (topics such water systems modelling, urban flooding and ecology), geo-engineering (dikes and foundations), geoscience and remote sensing (climate and satellite monitoring) and with the faculties of policy and management and architecture (sustainable delta design) and EWI (data, AI and numerical methods). Also, the partnerships within our sector are crucial to realize our research ambitions and make available findings. Examples of key partners are IHE, Deltares, Rijkswaterstaat, port of Rotterdam and several companies from the hydraulic engineering, dredging and off shore energy sectors.

7.4.2 People and community

- The excess workload in education is still felt in some specific areas of education (specifically in offshore, also in rivers, ports and hydraulic structures). The additional workload induced by the new MSc programme will be analysed and actively managed. Current and future education needs (e.g. engineering and design expertise) will be taken into account in future hiring and vacancies.
- Also, additional hirings or phasing out of other activities will be needed to address new developments (climate, AI, NBS). The previous assessment committee noted that “adaptation (topic switching) is more challenging without expansion of the group” (p9). Where possible, new developments and technologies are explored through collaboration with others at TU Delft. Flexibility of staff can also be encouraged, to grasp new, cross-disciplinary opportunities and ensure long-term career resilience.

- A major topic is the improvement of (i.e., reduction of) PhD duration. This has continuous attention and the recommendations of the internal working group (with staff and PhD representatives) will be implemented. Examples are increased attention for PhD supervision during the yearly evaluation cycle of staff, dedicated moments of reflection on progress and interaction between PhD and supervisor and a better distribution of PhD involvement in education.
- HE expects that the new Room for Talent policy of the Dutch universities will lead to a more diverse tenure track and HR policy, acknowledging both individual talents and ambitions of candidates as well as team contributions. It is anticipated that this could also support our ambition to attract staff with engineering and design expertise. HE is eager to be a frontrunner in the implementation of the new policy. This is also illustrated by the fact that HE staff has initiated interactions and discussion with the faculty's tenure trackers.
- Internal collaboration between HE and fields and disciplines is encouraged and included in current and new projects and proposals. To maximise project success in the very competitive national and EU calls, there is a clear focus on calls and opportunities with higher success rates. Where necessary, internal screening is applied to avoid that too many people apply to the same call. The start-up packages and other mechanisms (e.g. TKI - which is a top sector funding arrangement) will help new tenure trackers to set up projects..
- We have implemented more active coaching of and exchange between tenure trackers to come to a better preparation of the trajectory towards the career committee (VLC). Also, we will improve the link between the annual R&D cycle, and the longer term career development and assessment by the VLC. We will include the recommendations from the VLC in the annual R&D meetings and annual agreements.
- We stimulate an environment for individuals to grow. All promotions and staff are discussed within the department management team to ensure a "level playing field". Also, a template has been developed to report achievements (e.g. publications, grants received, PhD, MSc and BSc students supervised, organisational activities, recognition as team member) for those who want to be promoted to associate professor. This facilitates the comparison with peers. Inclusiveness remains a priority. Part of the inclusiveness is the option of having group leaders (section leaders) who are not yet full professors. At this moment, we are discussing the nomination of two or three new section leaders who will take over the role which is now fulfilled by a full professor. This discussion aligns with the broader discussion within faculty on the optimal organisation structure for different departments, providing a safe working environment and open atmosphere that is attractive to a diverse staff.



Safety in numbers in corona time

This picture accompanies a story about how our research into pedestrian crowd behaviour became even more relevant when the arrival of coronavirus forced us into a 1.5 metre society. All stories of science of the department of Transport and Planning can be found [here](#).

8. Transport & Planning

8.1 Mission

By performing excellent scientific research, T&P strives to contribute to key societal challenges, such as the impact of urbanisation, climate change adaptation and mitigation, as well as shifts to renewable energy sources, but also to improve health and well-being and equality, by providing *support to* and *means for* the sustainable (safe, secure, efficient, fair, resilient, healthy) design, planning and operation of multi-modal transport systems, while considering changing aims and technological possibilities. We do so by striving to be on the global forefront in all relevant transport and planning related disciplines aiming at responsible breakthroughs for societal problems, capitalising on our unique combination of excellent science, engineering and design. The T&P mission includes contributing to top-level MSc and PhD education in transport.

Given the changing mobility landscape, we believe that our research agenda and the supporting research organisation *needs to be sufficiently agile*. This means that next to the fundamental - often methodological - subjects like data collection, mathematical modelling of multi-modal transport systems, simulation and optimisation (in the context of control, planning and design), which are *strongly rooted in the Faculty's overarching research strategy*, topics like active mode mobility, new mobility services (and MaaS), transport resilience, AI, digital twins, spatial impact of electric and automated driving and climate change mitigation and adaptation, have been receiving more attention in the past period. Our newly introduced organisational structure - via so-called *Labs* – caters for a more robust approach to research portfolio management.

The objectives of the T&P research programme are as follows:

- T&P strives for top-level fundamental research that contributes to a more efficient and robust design and reliable operation of transport systems that meet mobility demands and respect scarce resources of land, environment and people. In doing so, T&P has a clear perspective to society-driven applications by using a multidisciplinary approach and in close cooperation with our stakeholders.
- T&P aims to conduct its research with a perspective on multiple transport modes and multiple user classes. The research uses rigorous quantitative approaches and is based on original empirical data, novel data-driven technology, state-of-the-art data analytics, modelling and simulation, assessment and optimisation in operations, planning and design. These are encapsulated in five *methodological and technological research themes (contributing to the cross-departmental research themes)*.
- T&P aims to conduct its research into fruitful and promising topics and approaches, around *six themes*: active mode mobility, smart public transport, digital railway traffic management, co-operative and coordinated traffic management, electric and automated vehicles and freight and logistics.

8.2 Developments since last research assessment

Since the last assessment, the organisation of T&P has been drastically changed by moving from a more top-down structure to a lab-based structure (collaborative teams). The new structure was carefully designed to provide more managerial and organisational involvement of our younger academic staff, to support academic entrepreneurship, to increase options for collaboration within the department and to make our research portfolio more flexible in response to the rapid changes in the mobility ecosystem. The new structure was crafted to address the main recommendations provided in the previous research assessment, as will be elaborated upon here.

Figure 15 provides an overview of the lab structure and the main research themes that T&P focuses on. The labs meet every month in the so-called *Overlab* to discuss their plans and further developments within and between the labs. The chair of the *Overlab* (a tenure tracker) is a full member of the T&P MT, where strategy is discussed and decisions made (both at the department and at the lab level). Also, meetings within and between labs are organised regularly. Moreover, the lab directors (a mix a tenure trackers, assistant, associate and full professors) are responsible for the management of their labs, whereas only the cross-laboratory management aspects are handled by the T&P management team and in the Overlab sessions. This management team is a mix of senior (two full professors) and younger (two associates and one assistant professor) academic staff and support staff members, including a representative of human resources, the PhD students and master students, respectively. *The new structure results for more involvement of younger academic staff in T&P's organisation and management.*

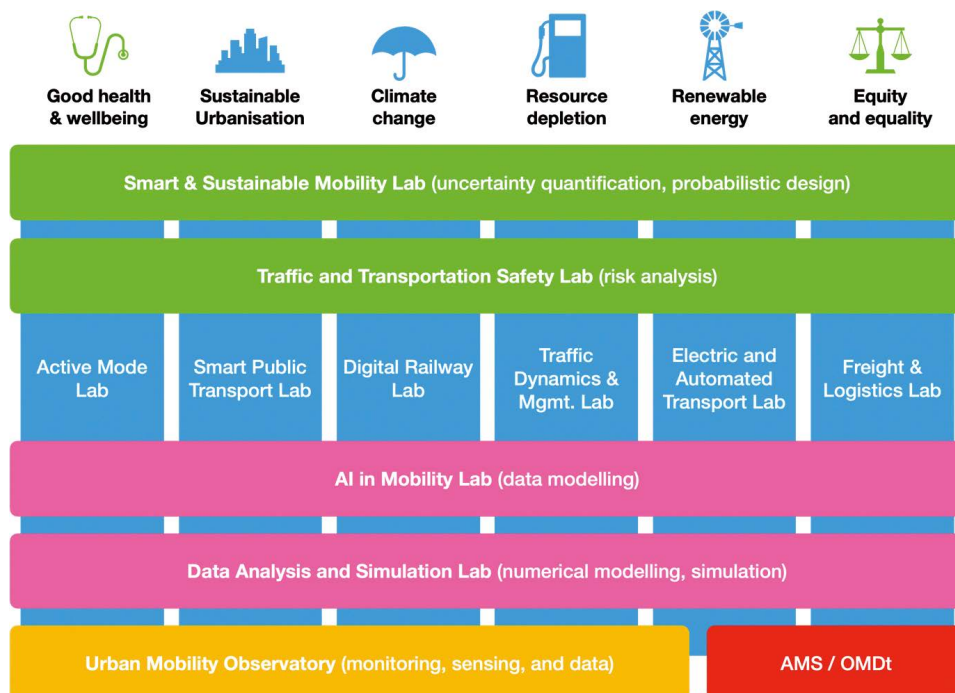


Figure 15 – Transport & Planning is organised via eleven T&P Labs, coordinated by (pairs of) assistant, associate or full professors. There are six thematic labs (blue vertical pillars) and five labs that are focusing on technologies and methods. The figure shows the key societal challenges that T&P focuses on. Data Analysis and Simulation Lab is referred to in the tekst as DiTTLab

Figure 15 shows at the top the societal challenges to which the research at T&P aims to contribute. As can be seen (and in more detail discussed in 8.3), these challenges include sustainability, health, inequality and safety, next to our more traditional contributions to accessibility and (service) reliability. In particular, the traffic and transport safety (TTS)

and the smart and sustainable mobility (SSM) labs focus *directly* on these issues (e.g., via offering design solutions), of course in close collaboration with the other labs. Our efforts on transport planning have been increased via the SSM lab and the SPTL. *This provides evidence that we have been paying stronger attention to the spatial impact of transport solutions, knowledge transfer to design components and safety and sustainability (air quality, noise, health, social cohesion).*

T&P has for a long time designed its research programme by actively looking for novel scientific perspectives to address the changing issues in the mobility domain, with heterogeneity (multi-scale, multi-class, multi-modal), uncertainty, robustness and interdisciplinarity as key programme characteristics. Its academic excellence has been recognised in the past research assessments. We have further strengthened our programme by hiring four new talented tenure trackers in key academic disciplines (network management in the age of connected and automated traffic, AI in transport, transport planning and network design and digital multi-modal network monitoring and management). We actively gather input to further shape our research agenda from our key partners (e.g., RWS, NS, ProRail, municipalities, consultants, service providers, tech companies, etc.) and collaborate to maximise our societal impact. The agility of the lab structure further improves our ability to adapt to topics for which there is a strong scientific or societal need. *This way, we believe we have developed a more robust approach to developing the rationale for focus areas.*

With our novel lab structure, we believe that our research has become more resilient since different subdisciplines can deploy catered approaches to agenda development best suiting their discipline (e.g., given different stakeholders, different focus on science-engineering-design). Diversification of strategies across the labs and funding results in a healthy mix of T&P research funding. A large number of NWO and ERC research projects have been awarded in the assessment period (including the NWO project STAD, the TTW project meaningful human control which both involve ethical and institutional issues of automated driving). At the same time, T&P has become more active (and successful) in H2020 and Horizon Europe projects, while collaboration with key stakeholders has been intensified and, in some cases, formalised (e.g., RWS, NS, ProRail, Amsterdam). The collaborations lead to research funding, but at the same time increases our potential societal impact.

T&P fosters a large national professional network. Collaborations (via joint projects, research funding, agenda setting) occur with all key stakeholders in the field. Main stakeholders are RWS, MinlenW, KIM, Province of Noord-Holland, municipalities (including Amsterdam, Rotterdam, Utrecht, The Hague and Delft), NS, ProRail, TNO, TØI, Dinalog, service providers (including Uber, GoAbout, Leaseplan), PT companies (e.g., GVB, RET, HTM, Arriva, Washington Metro), consultants (e.g., Arane, Goudappel Coffeng, Witteveen+Bos, RHDHV), OEMs (TOYOTA, NISSAN), tech companies (InControl, Technolution, Argaleo), etc.

A joint program with Rijkswaterstaat was developed in the field of Planning and Management of Smart and Sustainable Road Networks, resulting in the appointment of two assistant professors (Dr. Simeon Calvert and Dr. Shadi Sharif Azadeh). Via this program, we will further strengthen our collaboration with RWS on emerging topics in the mobility field. Via our standing collaboration with AMS, we have set up the IDM digital mobility management platform (together with the Amsterdam municipality). This has resulted in a sponsored assistant professor in the field of innovations in digital mobility management (Dr. Marco Rinaldi), which allows intensification of our collaboration with AMS and Amsterdam.

T&P is taking great care in informing the general public of their research activities. This occurs via public lectures, media and social media, blogs and opinion pieces. Moreover, T&P has increased its direct societal impact by working with CRE and the DUT Executive Board on innovations in the multi-modal transport system in and around the campus, with the ambition to turn the DUT campus in a sustainable mobility innovation hotspot (e.g.,

involving traveller preference research, network design, etc.). Campus has been equipped with state-of-the-art multi-modal real-time monitoring first to allow re-opening the campus to staff and students during Covid-19 and second to monitor multi-modal transport flows. Finally, T&P is coordinating the scientific research to support making on-site education possible again, via advanced indoor sensing of people in our buildings, advanced intervention design and state-of-the-art risk modelling. These initiatives fit in a larger stream of research that is related to Covid-19 and mobility.

T&P has further strengthened its international professional and academic network, with formal collaborations with companies such as Toyota, Volvo and universities such as BJTU, Tongji, DTU and Monash. *In all, these activities evidence that T&P has been working on increasing its societal impact*, in addition to its academic impact.

T&P and its constituent labs have been actively looking for cross-department collaborations on varying topics. These collaborations occur along the lines of *societal challenges* (e.g., urbanisation, climate change, change to renewable energy sources, growing inequality and health and well-being), translated into *T&P research themes* taken up by the various labs. Collaboration with other departments occurs also via contributions to *cross-departmental methods and technologies* (e.g., monitoring, sensing, data, numerical modelling and simulation, risk analysis, uncertainty quantification, AI and machine learning and design); more details are given in 8.3.

T&P leads the Transport Institute and has an active role in the new Rail Institute, which also fosters a stronger collaboration between ES and T&P. The structure and strengthen our collaborations within the Faculty and within the University. That said, many new opportunities will arise to strengthen our position within the Faculty which we will hope to capitalise on (e.g., the Pandemic and Disaster Preparedness Center)

T&P reviews its research portfolio, achievements and its impact on a regular basis, both internally and externally. The internal review is done every two years, leading to a SWOT analysis and to an assessment of the internal collaboration between the lab (ongoing process referred to as *Lab Dynamics*, led by an external coach focusing on organisational dynamics). Furthermore, an external SWOT has been made on the role of T&P by interviewing various stakeholders, as one of the initiatives of the *Social Impact Factory* which we have started up to review and improve our societal impact.

In the last few years, our focus has steadily shifted to publishing in top ranking journals (Transport Research A, B, C, Transport Science, etc.). Despite the novel structure, all (younger) assistant and associate professors are coached by senior staff (i.e., Prof. Van Arem, Prof. Hoogendoorn, Prof. Van Lint). In the yearly R&D cycle, emphasis is put on balancing not only quantity and quality (e.g., by actively discouraging an endless number of accepted papers in PhD theses), but on work and private life (as a response to the continuing perceived work pressure), on different job responsibilities and on ambitions, abilities and long-run challenges (instead of results), too. *In doing so, we challenge senior faculty members to mentor junior colleagues on how to balance quantity and quality for their career development.*

Career plans of Tenure Trackers are developed in the same way as in other CEG departments. Tenure Trackers meet regularly with their supervisors and with their peers (within or outside their labs). In many cases, the lab missions are based on the personal research statement of the coordinators and members. Currently, a mentor system is being set up as well.

The department has actively supported younger faculty members to increase their international exposure beyond publishing in international journals and presenting at conferences. Next to various research visits and sabbaticals, T&P has hosted a long list of international workshops and conferences (e.g., TRISTAN, hEART, RSS2017, MATTS, ISTTT, Forum /ISTS 2020). In most cases, younger staff was directly involved

in the conference organisation. Moreover, different labs organise workshops hosting international speakers.

In doing so, we aim to encourage junior faculty members to increase their international exposure.

8.3 Research and innovation strategy

8.3.1 Research themes

In the light of increasing *urbanisation*, our mobility ecosystem is subject to constant change caused by varying social, economic and technical trends; see *Figure 16*. These trends change our objectives: not only do we need to improve the accessibility of our cities, but we also see traffic and transport safety stagnating, liveability issues becoming more pressing, while both the *contribution of mobility* on and *the impacts of climate change* on mobility are becoming increasingly apparent. While increasing densification may provide interesting options for active mode mobility (“the 15-minute city”) and novel shared mobility services, scarceness of infrastructure may cause reducing levels of service for not only the motorised modes, but also the active modes and puts pressure on spatial demands of roads, railways and parking. Developments in smart and clean transport technologies and services as Smart sensing and management, Mobility as a Service, Electric and Automated Driving hold promise to make transport efficient, safe and reliable, while supporting the shift to *renewable energy*. Yet at the same time, these developments may have negative impacts as well. Urban sprawl may result from changing resistance of automated travel; novel digital services may not be accessible for all people leading to *digital inequality*; data may be used for other purposes than to improve accessibility. These are just examples of the complex interplay between various societal and technological trends that shape our research landscape.

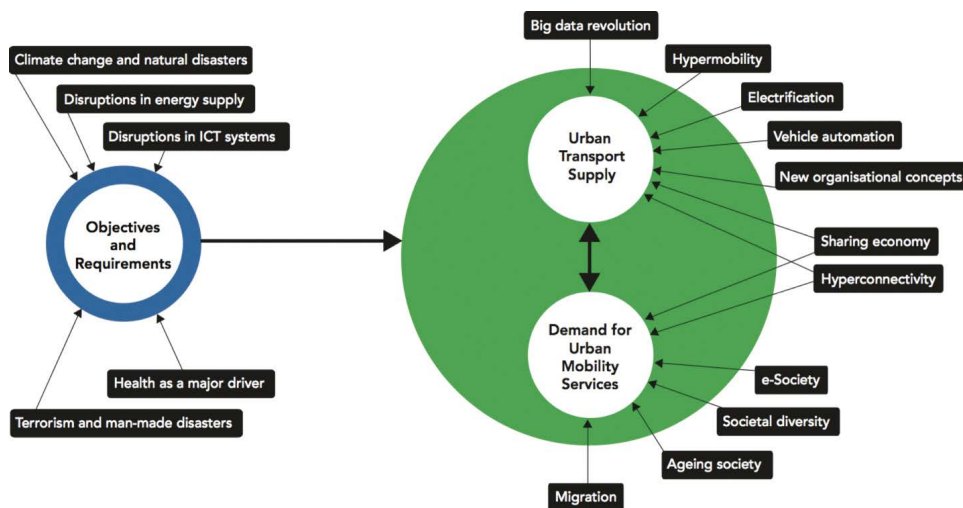


Figure 16 - Socio-economic and technological trends relevant for transport ecosystems.

The research of T&P comprises a broad range of themes that are organised via the T&P research labs, as discussed above. The themes have been determined from the interplay of key scientific - both theoretical and methodological - and societal trends and challenges and technological innovations. We aim to strive for a combination of topics that stem from important scientific, socio-economic and technological trends top-down (partly following from the Faculty strategy, but also including innovations such as AI, digital twins and data markets, IoT and 5G) and topics that originate from the interests and skills of the academic staff (e.g., MaaS, vehicle automation, crowd management, resilience). The key societal challenges to which T&P contributes are listed in the table below and linked to the *thematic T&P Labs*.

Table 7 – Overview of key societal challenges to which T&P contributes via its research and the thematic labs involved. The societal challenges ‘in blue’ correspond to the societal challenges listed in the faculty strategy. Those ‘in green’ are not explicitly mentioned at the faculty strategy, yet of importance to T&P.

Societal challenge	T&P research themes	Involved thematic labs
Urbanisation	Densification and accessibility; scarcity of infrastructure; multi-modal urban transport; coordinated and connected traffic management; shared mobility services; MaaS and demand responsive transit; urban and regional public transport planning and control; safe and sustainable active mode operations, planning and design; electric and automated driving (cars and trains), including interaction with vulnerable road users; city logistics and distribution	SSM Lab, SPTL, AMLab, DRTLlab, TDMaC, F&L Lab, hEAT Lab, TTS Lab
Climate change	Sustainable mobility; sustainable traffic management; energy-efficient driving; electrification of transport Evacuation modelling and management; resilience in traffic and transport	SSM Lab, SPTL, AMLab, DRTLlab
Resource depletion	Automation and land use; shared mobility (from ownership to use)	SSM Lab, SPTL, hEAT
Renewable energy	Electric and automated mobility; hydrogen-based transport; future energy systems and role of transport	hEAT Lab, SSM Lab
Health and well-being	Health and (active) mobility; liveability and transport; traffic and transport safety	AMLab, SSM Lab, TTS Lab
Inequality	Digital inequality, equity in transport	SSM Lab, SPTL

8.3.2 Research strategy

T&P has worked to retain its international status of one of the key groups in traffic and transport science worldwide (both in sheer size and in its academic impact). Our leading positions in experimental and empirical research, multi-class and traffic flow modelling of the various modes of travel, seamless multi-modal transport, automated driving, co-operative and connected network management and network reliability and robustness, has remained an important pillar in our research strategy.

In line with the Faculty strategy and in part via the new lab structure, we further strengthened our technological and methodological research efforts. Via the NWO Groot grant UMO, we are building an advanced multi-scale (in time and space) monitoring and data management system; the DiTTLab has developed the necessary infrastructure for advanced data analytics and simulation; via the AIMLab, we have invested in the novel field of AI and ML in Mobility via the recruitment of two new Tenure Trackers. The overarching SSM Lab develops data-driven, complex adaptive systems approaches, using a carefully chosen cocktail of agent-based modelling, system dynamics, optimisation and AI methods (with the AIM Lab) and cast into impact assessment tools and digital twins, capitalising on the knowledge developed in the thematic labs, to design, plan and run a smart and sustainable mobility system.

Table 8 – Overview of methods and technologies, T&P teams and methodological labs involved.

Method and technologies (in line with cross-departmental methods and techniques)	T&P research themes	Involved methodological lab
Sensing, monitoring and data	Experimental design, multi-scale sensor network design, data assimilation, data enrichment, data management, data security and privacy, data management and storage, AR and VR applications; IoT and mobility	UMO Lab
Numerical modelling, simulation	Agent-based modelling, multi-scale modelling, Lagrangian modelling, Smoothed Particle Hydrodynamics, hybrid modelling	DiTTLab
AI and ML (within scope of TU Delft wide AI initiatives)	Pattern recognition and clustering, short-term and long-term prediction, advanced statistics, causality, visualisation	AIM Lab
Risk analysis; uncertainty quantification, probabilistic design	Traffic safety modelling; network and transport system robustness analysis, contamination risk analysis, network optimisation under uncertainty, robust control and demand management, digital twins	TTS Lab; SSM Lab

T&P is working with other departments in the Faculty to maximise the potential for integrating the use of its experimental facilities. Examples are the use of its Digital Twin OMDt, tools for evacuation modelling and optimisation and AI technology for Pavement Engineering through a joint PhD project sponsored by RWS.

8.4 People and community

T&P has continued its appreciation of aspects other than scientific output and quality in the yearly R&D meetings, as well as in the intermediate progress talks with supervisors and junior/mid-level staff. Attention to group development, valorisation and societal impact, outreach, networking is being paid in these talks. T&P has emphasised increasing collaboration between its academic staff members, e.g., via the carefully designed lab organisation and the associated responsibilities.

For lab coordinators, vision and strategy development, as well as collaboration with the other labs is a returning point of discussion in both the R&D talks. The R&D meetings are always performed by two assessors (in most cases, Prof. Hoogendoorn and Prof. Van Arem). These talks are both retrospective and prospective, focusing on the personal development of the academic staff. The personal mission statement is an important starting point for these discussions and is often intertwined with the vision of the respective T&P lab. The fact that labs are generally coordinated by duos, increases further collaborative thinking of relating personal and group missions, further developing research leadership.

T&P has further increased the number of female academics. The share of female PhDs is around 50%; the share of female staff members around 25%. The current composition of the T&P daily management body (the T&P management team) includes three U(H)Ds, but also one PhD and one Master student (student association representation).

T&P has been very active in safeguarding the well-being of its staff and students during the pandemic. Activities entail professional coaching of supervisors, organising various on-line activities, setting up an intensively used Whatsapp group, bi-weekly personal notes from the department chair, and setting-up Covid-19 related joint projects.

8.5 Outlook

In the remaining period until the end-term assessment, T&P will be focusing on carefully assessing and fine tuning the new lab organisation. Focus will be on further embedding education in the lab structure (coordination of education efforts are now done at the MT level via our education coordinator, while courses are developed in the labs), further training and development on within and between lab communication and collaboration (the 'softer' side of the organisation, via the taskforce activity *LabDynamics*). Also, we are investigating options to include more staff members (e.g., lab coordinators) as assessors in the yearly R&D cycle. Coordinating a lab provides excellent "learning on the job" opportunities for academic leadership, which is further supported by the various training possibilities offered by the Faculty (e.g., recess college).

With the redesigned CE Master programme, we believe more opportunities to strengthen the collaborations with other CEG departments will arise. We believe that T&P's recognisable strengths in methodology and technology development (e.g., sensor network design, data analytics, simulation technology, digital twins, AI and ML, data fusion, IoT), as well as the role of mobility in various research themes rooted in CEG provides plenty of opportunities to realise this. T&P will continue to actively initialise these collaborations, supported by several existing (e.g., AMS, DAILabs) and new initiatives (Pandemic and Disaster Preparedness Center, Resilient Delta, AI Coalition).

We will further develop the Societal Impact Factory (SIF, under the leadership of Prof. Tavasszy) to continue to increase the options for societal impact. We will further strengthen our leadership role in the TU Delft via the Transport Institute, which will be renewed and revised (in terms of themes, facilities, etc.) from June 2021 onward. At the same time, we aim to strengthen our connection to the Topsector Logistics (via involvement of Prof. Tavasszy and Dr. Van Binsbergen). In performing the SWOT (presented in 8.4), several ways to further increase our impact (e.g., via collaboration and cocreation with industry and service providers) have been identified.

The Overlab provides great Internship opportunities and means to exchange best (and worst) practises. In fostering a safe environment supporting collaborative efforts between the labs, we believe that we can create an excellent environment for our excellent (junior) staff to flourish, both academically and personally.

8.6 SWOT

Let us finally go into the SWOT analysis of the T&P research programme. One of the recommendations from the research assessment was that a more balanced, self-critical SWOT was called for. To this end, we got both input from external input from carefully selected stakeholders (e.g., RWS, Technolution, NS, Goudappel Coffeng) and within the department (i.e., the lab coordinators). *Figure 17* provides the key results.

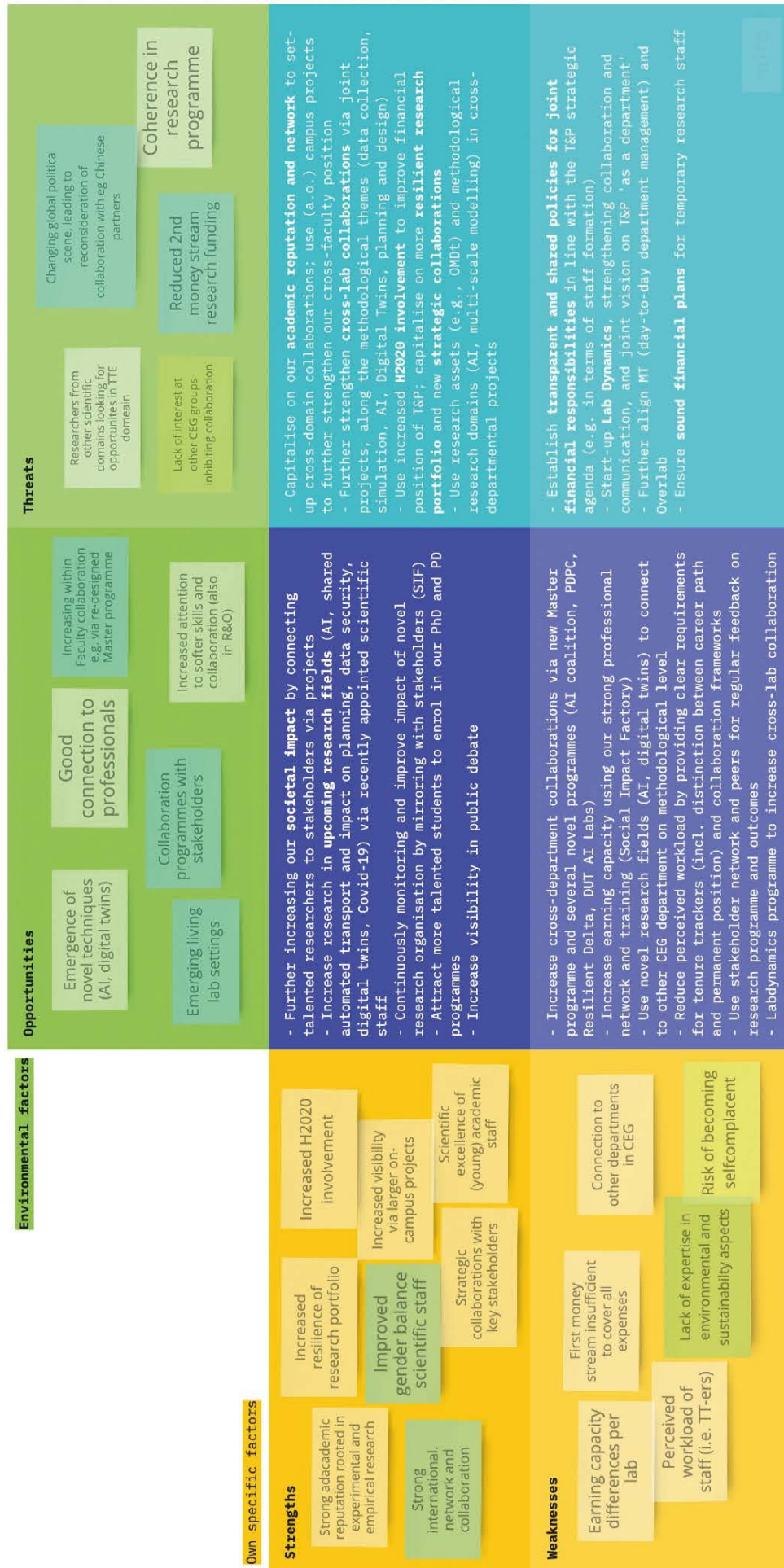


Figure 17 - SWOT Analysis including Strategies



Water with a bar code

This picture accompanies a story about our research into using advanced tracer technology with coded nanoparticles in the water, in order to improve filtering technologies of our drinking water. All stories of science of the department of Water Management are available online [here](#).

9. Water management

9.1 Vision and mission

Our mission is to advance fundamental scientific understanding and to develop innovative engineering technologies and water management solutions to address key societal challenges related to water systems and their interactions with humans. These societal challenges, as identified by the faculty CEG, include the impact of *climate change* and *urbanization* on water quantity and quality in natural and urban systems, environmental and human health risk assessments, as well as the associated adaptation strategies, innovative water treatment technologies to produce *clean water*, and solutions for *resource depletion* on food security.

Table 9

Key societal challenges			Research Themes							
Faculty			SDG's		Observation & modelling of water processes		Design, control and management of water systems	Urban water infrastructure SDGs	Water quality, treatment & reclamation	
Climate Change Clean Water Urbanization	Resource Depletion	Water Hazards (SDG 6 & 13)	NL	Urban rainfall		Urban flood risk management; water storage		Sewer overflows		Groundwater quality Emerging compounds
			GS	Water scarcity		Surface water pollution		Intermittent water supply systems		Surface water pollution
			NF	Floods						Clean freshwater scarcity
		Resilient Cities & Environments (SDG 9 & 11)	NL	Nature-based solutions		Real time control of water systems		Sustainable urban drainage systems		Novel techniques for water treatment; water and waste valorisation for industries
			GS	Flooding deltas and wetland deterioration				Citizen Science approaches		Local sanitation solutions; industry water reclamation
			NF	Evaporation and vegetation interaction				Pathways for urban climate adaptation		Water cascading / multiple water use
		Water & Health (SDG 6)	NL	Fate of pollutants in groundwater		Operation and control of water treatment		Monitoring and detection of plastics in urban waterways		Emerging contaminants (micro-pollutants,-plastics)
			GS	Water quality monitoring river basins		Water quality management river basins		Small-scale piped water supply		Treatment of urban sewage, industrial wastewater, and water reuse; arsenic removal; pathogen control
			NF							Antibiotic resistance
	Digital Water (SDG 11)	Water for Food (SDG 2)	NL	Remote sensing of water deficits in plants		Subsurface water storage; efficient irrigation		Drinking water system management		Reclamation techniques in hydroponics
			GS	Trans-African Hydro-Meteorological Observatory (TAHMO)		Water-Energy-Food nexus for management and design				Nutrient and water recycling for agricultural use
			NF	Global change impact on water supply						
		Digital Water (SDG 11)	NL	Opportunistic sensing of precipitation		Smart Water Systems		Cybersecurity		Remote monitoring; sensor-data fusion
			GS	Environmental monitoring with cellular communication networks						
			NF			Artificial Intelligence				

Table 9: Four department research themes and cross-cutting research topics that are aligned to four key societal challenges as formulated by the faculty and five sustainable development goals (SDGs) together with the major geographic focus areas of individual research topics (NL: Netherlands, GS: Global South, NF: other or no particular geographical focus). Note that geographic focus areas merely broadly illustrate the approximate focus over the past years. For many themes and projects this is not exclusively and can and will change over the coming years.

To achieve the above objectives and to maintain our leading role as international water competence hub we capitalize on the broad water expertise in the department, largely covering the spectrum of water-related topics. A crucial aspect to ensure future progress is our dedication to provide top-level education to train world-class engineers and scientists and to provide them with the interdisciplinary scientific background and skill-set that is necessary to develop effective, innovative, and sustainable solutions for current key societal challenges and those emerging in the future.

As a whole, the department follows four major research themes, as shown in Table 9: (1) Observation & modelling of water processes; (2) Design, control, and management of water systems; (3) Urban water infrastructure; and (4) Water quality, treatment, and reclamation. These themes integrate innovations in observational technology, modelling approaches, techno-managerial solutions, and engineered treatment technologies for a wide range of water-related problems at multiple scales, from local to global. To foster thematic coherence through knowledge exchange and collaborative research across the department and to maximize the societal relevance of the activities in the department, the four overall research themes are not only aligned to the four cross-cutting topics of key societal challenges as formulated at faculty level – *climate change*, *clean water*, *urbanization*, and *resource depletion* – but they also explicitly address several United Nations (UN) Sustainable Development Goals (SDGs 2, 6, 9, 11 and 13), with a special emphasis on water-related challenges in low- and middle-income countries in the Global South.

9.2 Recommendations of previous assessment and follow-up

In the previous research review the Water Management (WM) department received a positive evaluation with the highest possible score (“excellent”) for all three evaluation indicators: research quality, relevance to society, and viability. A few minor recommendations were provided. The actions taken to address these recommendations are described here in the following.

- (1) “[...] even though WM has been historically loosely sub-divided into two areas – water quality and hydrology – going forward it is planned to integrate these groups more strongly.”

Development since: WM was historically structured into two individual sections, Sanitary Engineering (“water quality”) and Water Resources (“hydrology”). These two sections have been integrated more strongly since 2018. This applies on the one hand to organizational aspects, i.e., before almost exclusively separate meetings at section level were held in WM; at present, meetings of the entire department with members from both sections are held. On the other hand, this also applies to increased research collaboration between members of both groups, involving joint MSc research projects, development of joint (PhD) research proposals, and more intense collaboration on research papers through increased focus on interdisciplinary topics.

This includes, for example, joint research projects for management of surface water quality in large river basins in Myanmar (Irrawaddy river) and Indonesia (Brantas river), water treatment with sustainable urban drainage systems and subsurface storage and re-use in urban settings (EU Climate KIC), as well as linking sanitation systems and drinking

water supply with groundwater and surface water quality (NWO DELTAP; NWO LOTUS-HR; African Water Corridor).

In addition, a clear development towards increased thematic coherence and collaboration, also across the entire faculty and in particular with the departments of Geoscience & Remote Sensing, Geoscience & Engineering, and Hydraulic Engineering, has started to emerge and is best illustrated by the increasing number of joint MSc and PhD research projects, such as the Delta Futures Lab as well as joint publications in scientific journals. The integration efforts are also underlined by the recent hiring decisions. Research expertise of many new staff members, e.g. Prof. Uijlenhoet, Dr. Rutten, Prof. Kapelan, Dr. Abraham, Dr. Taormina, and Dr. Mehta, is at the interface of the different research themes and are thus instrumental for strengthened integration.

(2) *“There is significant room for improved start-up packages” (for tenure trackers)*

Development since: introduction of a financial start-up package for tenure trackers at the faculty level of initially €50,000, which recently has been increased to a PhD-candidate. The increased integration and the resulting growing team spirit in the department is a critical additional aspect that allows new tenure trackers to find their way and research niches more easily. Continuation of that process will be important to more pro-actively support tenure trackers and young research staff.

(3) *“[...] further focus could be given to strengthen groundwater research”*

Development since: one new tenure-track staff member with research focus on groundwater, specifically *renewable* (shallow geothermal) *energy systems*, has been hired in 2020 (Dr. Bloemendal; 0.6 fte). Dr. Foppen from the IHE Delft Institute of Water Education has been associated to WM (0.2 fte) since 2020 to strengthen research on tracer and pathogen transport in groundwater. In the same year, Dr. van Breukelen, an expert on chemical hydrogeology, was tenured as associate professor in WM. Together with Prof. Bakker, specialist in physical geohydrology, this group organizes monthly discussion meetings to intensify internal and external collaboration on groundwater research, with varying external participants, including for example, experts on shallow geothermal energy from the department of Geosciences & Engineering or from IHE. In spite of this growth, the groundwater research group would further benefit from another tenure-track position with focus on groundwater – surface water interaction and water quality processes.

(4) *“The impact of WM can grow even further in the research field of water and food, anaerobic treatment and circular thinking”*

Development since: these fields have become among the faster growing ones in WM over the past few years. This is for example illustrated by the strong involvement of WM in the TU Delft AgTech Institute for agricultural production, established in 2020. Related research projects include remote sensing of crop moisture content (Prof. Steele-Dunne); sensor technology on plant condition (Dr. ten Veldhuis; 4TU Plantenna programme); water management innovations to enhance water availability for agriculture (Dr. van Breukelen; Topsector Water AGRIMAR); rainfall monitoring through mobile technology in Sri Lanka and Nigeria (Prof. Uijlenhoet; GSMA AgriTech Programme). With respect to anaerobic treatment and circularity, the following projects are illustrative: water/energy recovery to enhance sustainability of palm oil industry in Malaysia (Dr. Lindeboom; Delft Global); off-grid energy supply using small-scale digester systems coupled to fuel cell technology in Uganda (Dr. Lindeboom; Delft Global); ammonium recovery from animal husbandry and sewage treatment using electro-dialysis (Dr. Spanjers, Prof. van Lier; NWO, RVO); enhanced excess sludge treatment from sewage treatment plants in cooperation with Dutch water authorities (Prof. de Kreuk; STOWA, TKI, Paques); and techniques for wastewater treatment with anaerobic membrane bioreactors (Prof. van Lier; NWO, Evides).

(5) *“A programme such as WM that has a long history of success, may gradually be taken for granted [...] and loose support. This should be avoided at all costs”*

Development since: the development of the new Environmental Engineering MSc programme is very important from that perspective, as WM will have a core position in that programme, emphasizing its central role at the interface of atmosphere, soil, and vegetation, at and near the Earth surface and as such, its importance for societal and ecosystem stability. The already high degree of international interest in our program is illustrative for the position of our research group in a global context. The central role of WM for society is explicitly reflected in various SDGs and in key societal challenges formulated at faculty level, which are addressed by the individual research themes of WM (Table 1) and further underlined by recent large-scale projects, such as the African Water Corridor, a privately funded programme of Water for Africa, or the EU-funded Zerobrine project on waste valorisation. Strong market connections to and collaboration with water companies (e.g. WMD, Waternet, Evides), research institutes (e.g. KWR, Deltares, KNMI), engineering consultants (e.g. HKV, Royal Haskoning) and administration (e.g. Rijkswaterstraat, Water Boards) further illustrate the direct relevance of WM for developing solutions for water-related societal problems. Although it is a challenge that the Faculty takes the excellent national and international standing of WM for granted, the support from Sectorplan Engineering (1 position) and Van Rijn funding (1 position) suggests sufficient recognition. In addition, WM will probably also benefit from the Sectorplan Earth and Environmental Science.

(6) *“It is important for WM to be clearly visible to students in the Faculty. Earlier introduction of students to topics in WM in the degree programs would help.*

Development since: as indicator of the increased visibility to students early in their studies, the faculty-wide fraction of students who do their BSc thesis on a water management topic has increased over the last few years from previously <15% to about 25 – 30%. Further strengthening the visibility of WM at BSc level will be a major emphasis in the upcoming years: WM is at the core of the newly developed Environmental Engineering MSc programme, which features a dedicated Water Resources Engineering track. Together with considerable cross-over contributions of WM to the other two tracks of that programme as well as to the other two newly revised MSc programmes in the Faculty, i.e. Applied Earth Sciences and Civil Engineering, this will also considerably increase the exposure of WM and its visibility to students early in their studies. However, obtaining more visibility in the BSc programmes (e.g. Civil Engineering) is still to be addressed.

9.3 Research and Innovation: Developments since last research evaluation

9.3.1 Research Themes

Observation and modelling of water processes

This theme adopts a holistic, integrated, and systematic approach to develop innovative technology for observations of different components of the water cycle, and to use these observations to improve hydrological and groundwater models for more reliable quantitative descriptions and predictions of seasonal water supply, floods, droughts and other water-related hazards. A major development over the past years includes a strong thematic focus to better observe, describe, and quantify evaporation processes and the associated effects on hydrological extremes. This involves, in particular, the role of vegetation and ecosystem adaptation in response to changing environmental conditions and has high potential for the improvement of predictive models that provide representations of the effects of ecosystem adaptation in a world under change. As such, the theme directly contributes to several SDGs (Table 9) as well as to the scientific decade 2013–2022 “*Panta Rhe*” of the *International Association of Hydrological Sciences*.

Over the last period, a wide spectrum of different key research projects contributed to this theme. For example, in the Netherlands, several EU- and NWO-funded projects developed and implemented novel methods including optical fibre sensors to measure groundwater velocities and evaporation as part of the Ruisdael observatory sites (National Roadmap for large-scale research facilities) and to monitor dikes and landslides (DOMINO). In the STW WaterTagging project, methods are developed to use DNA-microparticles for tracing and modelling water flows. The Trans-African Hydro-Meteorological Observatory (TAHMO) established a network of 20,000 weather station across Africa to increase climate resilience. Similarly, the African Rainfall Project generates high resolution (1km) weather predictions over the continent, while the EU-funded TWIGA project uses novel sensing and computational approaches to develop new geo-services for Africa. In a further large-scale NWO-funded project, innovations in observation techniques and model approaches were used to quantify the sources and magnitudes of water fluxes at high spatial resolutions in the Zambezi River Basin, providing the basis for sustainable management to enhance water, food, and energy security (ZAMSECUR). Several projects contributed to a better understanding of atmospheric moisture sources for precipitation extremes (NWO VENI van der Ent) and the associated role of vegetation feedback for the generation of droughts (NWO Refugees in Science). Related to the above, in a project funded by Rijkswaterstaat, the adaptive and temporally evolving role of vegetation was formalized in process-based hydrological models and is a critical step towards improving flood and drought predictions in a changing climate. The adaptation of machine learning methods and models for predictions of hydrological extremes was explored in two projects (DEUCALION II, EU-LEaDingFellows). In addition, a comprehensive open-source software package (Pastas) for groundwater timeseries analysis was developed, funded by STOWA and several drinking water companies. A further important project towards coherent and efficient computational model implementations is the high-resolution, global operational global forecasting modelling framework including data assimilation and lateral water routing (eWaterCycle).

Design, Control, and Management of Water Systems

This theme is focussed on the interaction of humans and water systems. This involves, on the one hand, the design, modelling and control to optimize the operations of water infrastructure, such as irrigation systems, reservoir operations, pumping systems, water treatment, or drinking water systems, and management of groundwater quality towards sustainable global change adaptation with special emphasis on urbanization in the Global South. On the other hand, this theme seeks to quantitatively describe the link and feedbacks between water systems and socio-economic dynamics in human societies. As such, the theme explicitly addresses several SDGs (Table 9). Major research lines emerging over the past few years involve a growing focus on the Water-Energy-Food-Security nexus to improve quantitative descriptions and predictions of interactions within that integrated system as well as development of “Smart” Water Systems for more efficient use and management of water resources.

Specific research projects include the development of decision support tools for the optimisation of the urban food-energy-water nexus (ENLARGE, URBANWAT). Another initiative funded by the Top Sector Water Technology in collaboration with multiple water boards, the Ministry of Infrastructure and HKV Consulting is the development of optimal control for open canal systems for demand response to prepare for the Energy Transition (PCOCS). Similarly, a further project contributed to the development of innovative control methods for irrigation based on remote sensing data (IWACA-TECH). Related to that an integrated surface water-groundwater model to reconcile agricultural and environmental water demand in endorheic irrigated river basins was designed in collaboration with the Iran University of Science and Technology. In an Indonesian-Dutch collaboration (Brantas) funded by the Fund Sustainable Water, the water quality management of a large Indonesian river basin is strengthened by linking water quality monitoring procedures,

policy measures and stakeholder interests. Similarly, the WaterEfficiency project in India delivered a socio-hydrology model that integrates climate and price movements to allow farmers to reduce their water risk and ensure sustainable livelihoods. Decision-making processes among African and Asian farmers concerning irrigation technologies and land use in relation to governmental and business interventions were investigated in the Farmers Strategies' project, with the aim to both understand and better support these decisions. Related to the above, the longer-term consequences of the many short-term interactions between humans and water processes in current and historical settings are investigated in the Human-Water Interactions project with the aim to provide insights for future decision making.

Urban water infrastructure

This theme is focused on addressing issues across the urban water cycle related to planning, rehabilitation, operation, control, and maintenance of urban water infrastructure (UWI). This covers both quantity and quality aspects of drinking water and urban drainage, but also aspects of integrated urban water management. More specifically, over the past years the focus was on new urban water transport systems, including water-saving technologies on existing drinking water and sewer systems, asset management, real-time control of urban drainage systems, transport of sediments in sewers, development of smart water systems based on artificial intelligence, improved modelling of intermittent water supply systems, drinking water temperature, sustainability and circularity assessment and improved decision-making in UWI. As such, this theme directly contributes to several SDGs (Table 9) and the *Digital Water* agenda of the *International Water Association*. Specific research projects include: (a) NUWTS, funded by the TKI Watertechnologie and eight water/other companies, focusing on the design of new urban water transport infrastructure based on resource recovery and water saving strategies; (b) AldroLab, major initiative focusing on the development of novel artificial intelligence-based methods and tools for modelling and rehabilitation / planning of drinking water and urban drainage systems; (c) EU H2020 Wider Uptake project aiming at improved sustainability/circularity of water and wastewater reuse solutions in the urban environment; (d) SewerSense project (NWO-TTW funded) developing new methods and knowledge for automated sewer condition assessment from CCTV images, deterioration and failure modelling of sewers and generation of risk-based asset inspection plans; (e) improved operational / real-time control of urban drainage systems (with waterboard De Dommel) and wastewater treatment plants (with KWR and Waternet); (f) EU Climate KIC Bluebloqs project on capture of urban storm water, pre-treatment with biofilters, subsurface storage with aquifer storage and recovery and re-use for urban irrigation; (g) detection, quantification, monitoring and management of plastics in urban waterways (with Rijkswaterstaat); (h) improved decision making for UWI by means of multi-criteria decision analysis (with Waternet) and serious gaming (EU H2020 Wateragri).

Water quality, treatment, and reclamation

As a consequence of increased urbanisation, population growth and climate change, good quality freshwater becomes scarce and multiple use seems a logic solution. Therefore, research is conducted to seek innovative, advanced and robust processes for domestic wastewater, industrial process water, municipal sewage, surface water and groundwater, which use little (or no) fossil energy and resources. Such techniques aim for resource recovery and zero material losses. In addition, reclamation of energy and raw materials from waste streams is studied to enhance sustainability and circularity in the urban water cycle. Ammonia and biogas recovery are targeted in combination with adequate sanitation, both in the Netherlands and (rural) applications in the global south. Research has resulted in the development of anaerobic (membrane) bioreactors for industrial water recovery and highly purified discharges, recovery of energy from streams with high ammonia concentration, ceramic membrane filtration for water and salts reclamation and treatment of produced water, adsorption of compounds of emerging

concern with zeolites and biological arsenic oxidation, amongst others. The research contributes to several SDGs, including governance and societal aspects on technology adoption and behavioural changes. Specific research projects include innovations in slow and rapid sand filtration (VIDI van Halem; 2 NWO-TTW Partnership Programmes on Sand Filtration); removal of agrochemicals and plant pathogens with aquifer storage, transfer, and recovery to provide irrigation water in dry summers in the Dutch coastal area (NWO Topsector Water); removal of organic micropollutants with zeolites and subsequent oxidation with ozone (AdOx, NWO-TTW Partnership Programme CEC); development of ceramic membranes with SiC to avoid fouling during water filtration (SUCCIC OTP NWO-TTW); valorisation of salts from brines during industrial desalination (Zerobrine, EU-Horizon 2020); concentration and recovery of ammonium using (bipolar membrane) electro-dialysis coupled to solid oxide fuel cells for energy production or to produce high-quality chemical end-products (N2kWh, NWO-TTW in partnership with VLAIO; Circulaire N, DEI-RVO project with water authorities). In addition, several projects with direct and specific societal relevance in the Global South, such as water treatment of waste streams in New Delhi (LOTUS-Hr, NWO), three projects on arsenic removal and water reclamation, in the context of Urbanising Deltas (UDW-WOTRO) and development of implementation pathways for water scarcity alleviation in Sub-Saharan Africa (African Water Corridor, UfD) were carried out. Besides the focus on key challenges defined by the faculty and SDGs, the societal relevance of research in WM is underlined by the acquisition of major funding as elaborated above. Strong market connections to and collaboration with water companies (e.g. WMD, Waternet, Evides), water authorities, research institutes (e.g. KWR, Deltares, KNMI), engineering consultants (e.g. HKV, Royal Haskoning) and administration (e.g. Rijkswaterstaat, Waterboards) also illustrate the relevance of the department for developing solutions for water-related societal problems. Societal impact of research in the department is further strengthened by the emphasis of many projects on developing countries in the Global South (e.g. Brantas, TAHMO, TWIGA, ZAMSECUR, LOTUS-HR, African Water Corridor). In addition, the societal impact of the research in the department is exacerbated by efforts to disseminate research output through open access channels whenever possible.

9.3.2 Research Strategy

The above-described developments in the research themes are closely linked to changes in staff and organization of the department. With a view to cross-disciplinary challenges in the field, the boundaries between the Water Resources and Sanitary Engineering sections in the department have been gradually dissolving. This followed a deliberate decision towards a more collaborative and integrated approach of the entire department inspired by the key societal challenges defined at faculty level and the associated SDGs outlined in Table 9. Research from different parts of the department therefore explicitly aimed to address common research topics along the four research themes (Table 9), which has resulted in an increasing number of collaborative research projects and publications within the department. Besides maintaining strengths and the role as a global player in the four broad research themes, all four research themes have contributed to the development of cross-departmental methods and technologies in the faculty, in particular related to monitoring and sensing as well as to modelling and simulation. In recent years, such integrated research has been particularly successful in the Global South. An important development in this respect is the large-scale collaborative and cross-disciplinary African Water Corridor project that seeks to eliminate water shortages in the agricultural and household sectors. The integration process in the department further benefitted from strategic hiring decisions for new staff. They bring in new expertise that is at the interface between the different research fields in the department: Prof. Kapelan (urban drainage and drinking water distribution systems), Prof. Uijlenhoet (opportunistic sensing), Dr. Foppen (pathogen transport; IHE; 0.2 fte at TUD), Dr. Mehta (computational fluid dynamics), Dr. Rutten (delta planning), Dr. Taormina (AI and cybersecurity), and Dr. van der Ent (atmospheric water cycle).

With a total of 113 researchers (54 fte), including 16 Post-Docs, staff has remained stable over the last few years. The department currently counts 141 PhD candidates and an additional 58 PhD candidates have graduated since 2018. Overall, the department has maintained a healthy financial position over the past period, successfully following a strategy to obtain a balanced portfolio of direct funding, research grants, and contract research. The individual proportions of contract research and the contribution of research grants (e.g. NWO, EU) have remained stable over the past period, reflecting the strategy of the programme.

9.3.3 People and Community

To be effective, the implementation of integration efforts was accompanied by increasingly transparent and inclusive decision-making processes as well as efforts to strengthen diversity in the department. This directly followed the strategic development at faculty level and included measures such as opening the department management process by broadening the management team with department representatives of various faculty committees and by increased representation of younger staff as well as of MSc and PhD students. In addition, the systematic inclusion of all staff in regular strategic meetings at department and section levels was instrumental to further develop integrated research strategies and models for an organizational structure of the department to best meet future challenges. In this ongoing process the department has increasingly adopted a flexible model of research teams with a strong informal component. More specifically, staff are encouraged to organize themselves to collaborate in flexible compositions on specific research lines. Such an approach combines the advantage of a flat hierarchy with an optimal use of the available multi-disciplinary expertise and fosters collaboration, integration and identification with the department. In addition, the emerging team spirit has shown positive effects, in particular concerning the development of robust research profiles of early career researchers and tenure trackers as it helps them to find their way and niches of expertise more easily. Overall, this development has received broad support throughout the department and the faculty.

The broad inclusion of staff has also been key in the ongoing re-development of the MSc programme. A new Environmental Engineering MSc programme has been conceived, in which the Water Management department will play a central role. This central role is reflected in the individual track Water Resources Engineering (WRE) within that programme and considerable cross-over contributions of the department to the two other tracks, Resource and Waste Engineering, as well as Atmosphere and Environment Engineering. The learning lines of the WRE track explicitly reflect the overall research themes of the department as defined above and thus smoothly integrate with the research strategy. In addition, the department of Water Management will substantially contribute to the other two new MSc programmes, Applied Earth Sciences and Civil Engineering, respectively. This will facilitate an efficient direct and intense cross-pollination of interdisciplinary research and education. The relevance and position of the department in the new MSc programmes will not only underline the department's role for society but also strengthen its position in the faculty and increase its visibility to students early in their studies.

Over the past years the department also pursued an active strategy towards an equilibrated gender balance among faculty members. This is reflected by the balanced proportion of newly hired full-time staff, 50% of which are female (Dr. Blokker, Dr. Rutten, Dr. Lompe). Similarly, promotions to Associate Professors (Dr. van Halem, Dr. ten Veldhuis) and Professors (Prof. Steele-Dunne) in the department since 2018 are also characterized by a stable gender equilibrium.

9.4 Outlook

9.4.1 Research Themes

The momentum built around the current research themes in the department will be used to maintain strength and to further intensify research efforts along these lines. The increasing societal relevance of climate change, land-use change, water stress & nuisance as well as urbanization, in particular in the Global South, provides a clear thematic baseline along which an increased need for research and the associated opportunities can be expected over the next decade. As department of Water Management, we therefore envisage a growing strategic emphasis on impact and adaptation along the key societal challenges – climate change, clean water, urbanization, and resource depletion – defined at faculty level and SDGs identified above (Table 9). The recently launched joint initiative Delft Water brings together the major players in the Delft water sector, including TU Delft, IHE Delft, Deltares, the Water Authority Delfland and the city of Delft and aims to bundle, focus and coordinate regional water-related research. Reinforcing long-standing bilateral collaborations between these institutions, such as joint PhD and PDEng research projects, shared laboratories or mutual part-time appointments, can be expected to provide an important further step to maximize the relevance and impact of future research in WM.

More specifically, the theme “Observation and modelling of water processes” has considerable potential to develop innovative methods for improved monitoring and predictions of global change impact on water-related hazards such as floods, droughts, pollution and water scarcity and its direct effect on humans and ecosystems. Specific research initiatives that are planned or have very recently been launched include for example the development of an opportunistic precipitation sensing network (OPENSENSE, EU Cost-Action). Another example is the involvement in an isotope tracer-based study to describe vegetation-related processes that control subsurface water mixing and groundwater recharge (WATSON, EU Cost-Action). Related to the above are several complementary initiatives to develop landscape-scale methods to quantify temporally-varying vegetation-related parameters of hydrological- and land-surface models in response to climate and land-use change, to improve predictions of floods and droughts in collaboration with Rijkswaterstaat (CATAPUC) and ETH Zurich (LOVEFADS, SNF). Pollutant transport pathways (run-off, submarine groundwater discharge) from land towards coral reefs in the Dutch Caribbean will be measured and modelled, and cost-effective land-use and water management strategies will be assessed (NWO SEALINK). The theme “Design, control and management water systems” will focus on pressing adaptation issues, such as adaptation to global change-induced flooding of the many delta regions and coping with extended periods of droughts as well as polluted waters, in particular in the Global South, but also to develop strategies to make water infrastructure more resilient global change. A major initiative (AquaConnect) here is the development of optimization models for water distribution in smart-grid systems. Related to that topic but with a very strong cross-disciplinary element, is the ongoing initiative to establish a large-scale collaboration with Amrita University (India) to tackle challenges of sustainable water management, including reservoir sedimentation, urban water distribution, and storm water management, as well as pathogen and emergent pollutant movement in and elimination from water systems at multiple scales.

The “Urban water infrastructure” theme will focus on adaption for more resilient water systems and cities under global change. This will involve integrated water management based on novel technologies for efficient water use following circular economy, nexus and sustainability principles. Another focus will be digital water, including development of smart water systems and their cybersecurity, making use of advanced sensors and artificial intelligence. A specific research initiative that is planned in this theme over the next years includes the Urban Water Corridor, which in correspondence to the African Water Corridor project, seeks to address and eliminate factors that contribute to water shortages in urban settings. The theme “Water quality, treatment and reclamation” will

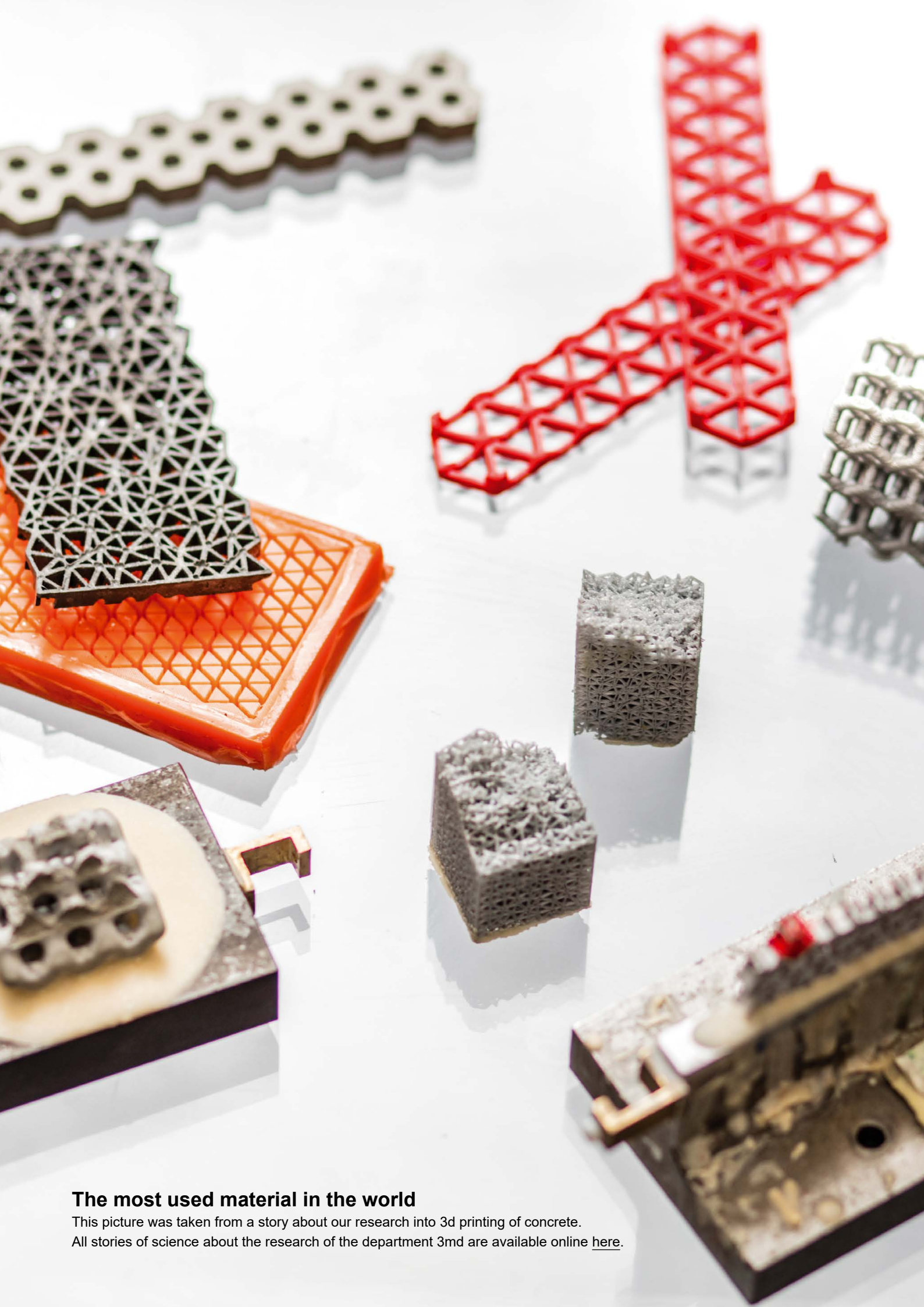
develop novel treatment technologies, including water reclamation, removal of emerging compounds and raw material recovery from waste streams for enhanced circularity with special attention to different technological requirements in the Global South, also in the context of the African Water Corridor, and in industrialized countries, respectively. Other developments include climate change-proof design of technologies for energy-efficient as well as high-capacity and low-cost water treatment. This is amongst others reflected in the initiative for a NWO-NWA (Nationale Wetenschapsagenda) proposal on integrated urban water management strategies for both the Netherlands as the global south. In addition, initiatives are developed for leading EU consortia in the context of ZERO-POLLUTION.

9.4.2 Research Strategy

The central position of the department in the newly developed Environmental Engineering MSc programme will strengthen the profile of the department. This will lead to more visibility and will allow students to grasp the relevance of water-related topics early on, which in turn will be instrumental for attracting highly talented students. Further consolidation of the department integration process and more directed and systematic outward communication will generate increased exposure and impact. In combination with the momentum from targeted interdisciplinary research along the four main research themes and the four research topics aligned to key societal challenges as formulated by the faculty – *Climate Change, Clean Water, Urbanization and Resource Depletion* (Table 9) – these measures will be key to attract excellent academics who will further sharpen the research profile and open up alternative funding opportunities. The department is also committed to contribute to the development of cross-departmental methods and technologies, in particular for monitoring and sensing as well as modelling and simulation, as defined at faculty level to further strengthen methodological and technological coherence across the faculty. In general, we seek to maintain a balanced funding portfolio with a mix of personal grants, fundamental research projects and more applied projects in cooperation with industry as well as co-funding schemes to address local and regional water-related problems, with a focus on developing countries in the Global South. Overall, we also aim to keep the staff-to-student ratio stable to ensure high-quality supervision.

9.4.3 People and Community

The current efforts towards transparency, inclusiveness and diversity in the department will be maintained by continuing the active involvement of staff in decision-making processes in general and ensure a gender-, age- and function-balanced representation of staff in the department management team, in particular. Similarly, the department will continue to actively pursue a hiring and promotion policy so that the proportion of female staff will eventually reflect the proportion of female PhD students. Following strategic choices at the faculty level, the department will also increase efforts for more appreciation of individual contributions to group responsibilities/output, establishing and maintaining external relations and societal outreach. This will be accompanied by systematic guidance and efforts to provide staff with training opportunities. To provide MSc and PhD students a forum for mutual support and exchange among themselves but also with staff, in particular given Covid-19 related challenges, the department has together with the PhD council and the MSc student association (Dispuut Watermanagement) recently launched an initiative of peer meetings. These meetings involve, amongst others weekly speakers and discussion groups with changing invitees from TU Delft staff and industry. Together, these measures will be instrumental for staff to more effectively develop their individual talents and therefore reach excellence in specific aspects, which in turn has the potential to reflect back on and further strengthen the research profile of the department.



The most used material in the world

This picture was taken from a story about our research into 3d printing of concrete.

All stories of science about the research of the department 3md are available online [here](#).

10. Materials, Mechanics, Management & Design (3MD)

10.1 Mission

3MD focuses on the design, mechanics, materials and management of civil infrastructures and buildings. A multi-scale research approach is followed, starting at micro-scale (materials), to meso-scale (components/structures) and to macro-scale (infrastructures/systems). The department governs the entire life cycle from develop, design, test, build, maintain, operate to demolish or reuse. 3MD has strong competences in modelling and design for both civil infrastructures as well as buildings. The department strives for:

- top-level fundamental and application-oriented research, supported by excellent and unique experimental and numerical facilities; this research has a mono-, multi- and trans-disciplinary character;
- an open, professional and stimulating environment for students and young researchers to develop their full potential.

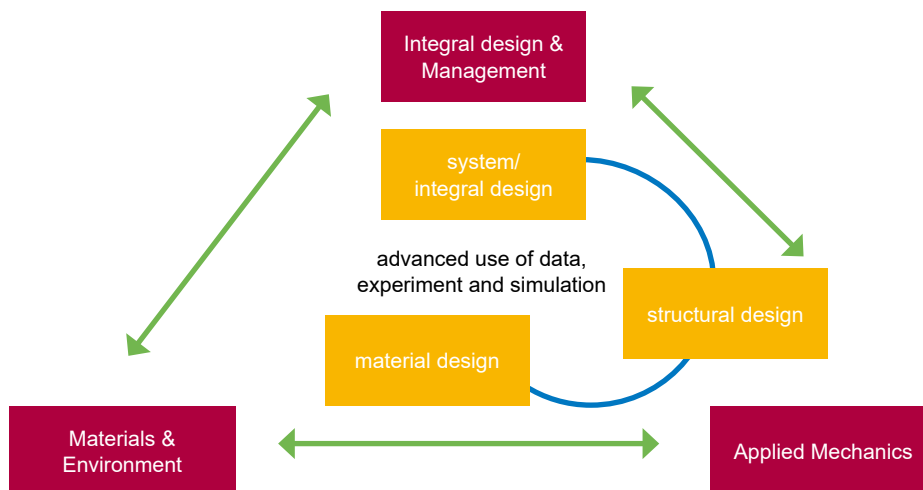


Figure 18: Schematic overview 3MD

The societal and scientific challenges 3MD is contributing to resolve are:

- an optimized resilience of buildings and infrastructure to increased loading, natural hazards and anthropogenic threats;
- an increased sustainability by integral solutions to reduce negative environmental impact;
- the transition to renewable energy systems from materials, mechanics, management and design perspective;
- the development of innovative and smart materials, construction technologies and design principles to create infrastructure and buildings with increased functionality.

These challenges are closely linked to the societal challenges as defined in the strategy of the faculty (see 10.3). Common threads through these activities are (i) multiscale design: from micro (materials) to meso (structures) to macro (integral systems), (ii) sustainability/circularity and (iii) digital solutions by properly combining physics and data. 3MD has profound fundamental knowledge as well as strong relations with construction and design practice. In Figure 18 the department structure is presented with the three groups Materials and Environment (M&E), Applied Mechanics (AM) and Integral Design and Management (IDM) which correspond to the three different scales.

3MD has a broad and multiscale research portfolio and is also deeply involved in both BSc- and MSc-education, providing basic knowledge as well as research-driven education.

10.2 Recommendations of previous assessment and follow-up

The assessment committee addressed a number of recommendations for the former Department of Structural Engineering (StrE). Since the size of this department was considered as limiting with respect to management of the internal processes and coherence, it was decided to split StrE into two departments, each with their own management: Engineering Structures (ES) and Materials, Mechanics, Management & Design (3MD). The two departments have common responsibility for the educational programmes and also strive to cooperate in joint acquisition of large multi-disciplinary projects. Because of this organizational change, not all recommendations do apply, or only partly apply to 3MD. In *italic* these recommendation are mentioned in the following.

Heterogeneity: The former department of Structural Engineering (StrE) was regarded as a heterogeneous department. The split enabled the 3MD department to define a clearer and coherent research program and to form a better organizational unit. 3MD has a stronger focus on the generic principles of structural engineering and the research program of ES is defined more from specific materials perspective. In the past years a regular scheme of staff meetings for exchange of knowledge and ideas was organized, resulting in new connections and joint projects. Furthermore, social meetings have been organized to further develop a highly motivated, connected group of staff members as well as PhDs and Postdocs. Accommodating the entire 3MD department on the 6th floor of the CEG building also improved coherence. Defining the connecting themes (i) design, (ii) sustainability/circularity and (iii) machine learning/digitalisation in a multi-scale fashion proved a good way forward to increase collaboration between individual researchers and research groups. Between departments and faculties, increasing collaboration has been established with groups at the departments ES, Geoscience & Engineering (GSE) and groups within the faculty of Electrical Engineering, Mathematics & Computer Science (EEMCS), the faculty of Technology, Policy & Management (TPM) and the faculty of Architecture.

Gender balance: 3MD is not automatically replacing a staff member when he or she leaves, but always considers possible changes from a strategic long-term perspective. An additional impulse to renew staff was given by additional governmental funding through the Sector Plan and the Van Rijn scheme. In profiling new positions and in the selection process, significant attention is paid to appoint scientists with excellent educational, research and soft skills. During the recruitment process for all new positions, also because of the weak gender balance, much attention was paid to attract female scientists. At first by critically reviewing the advertisement texts to be attractive to female applicants, by using national and international networks (also by asking female colleagues), and by making use of external recruitment assistance. As a result of the successful recruitment campaign, the number of female candidates significantly increased. Although a number of female candidates, in the end, did not accept the position, three female scientists were eventually appointed out of eight vacant positions.

Strengthening particular research fields: Within 3MD two research fields required a more focused research plan: Structural Design (as part of AM) and Integral Design and Management (IDM). Both groups are heavily involved in education, but staff changes made it possible to change research direction within these groups and add capacity. Structural Design is strengthened by appointing a full professor Structural Design and an assistant professor Parametric Structural Design and Digital Fabrication, both with a more academic profile than the present staff members, having an industrial background. This enables the group to create a more visible profile in research, but also linking the group further to other design-related groups within the department.

Within IDM three new assistant professors were appointed (Engineering Asset Management, Transdisciplinary Design, and Economics of Civil Infrastructure). Appointment of these assistant professors leads to (i) more research capacity and competences, and creates (ii) horizontal connections, since all positions have, on different scales, design aspects. More attention is paid to the question which design process in civil engineering generates maximum societal value by appointing an assistant professor Economics of Civil Infrastructure. With appointment of the new assistant professor Transdisciplinary Design the group IDM is linked with design expertise (structural design, materials design, multiscale modelling, construction technology, engineering asset management) on various scales in the department, also linking within the faculty (HE, TP) and with other faculties (TPM, Architecture).

Extending networks in society: Networks have been extended, by involving young staff members in current networks (NAM, government [e.g. ministries and governmental advice committees], TNO, RWS), but also by adding new networks (Provinces, industry, network around fire safety).

Laboratory and computing facilities: Our laboratory, the Microlab, which is renowned for the micromechanical research, is a strong asset of the department, and although costly to maintain, we constantly seek opportunities to invest. A recent large investment was the new Environmental Scanning Electron Microscope (ESEM), an investment of approximately k€300. The facilities are also used by other departments, e.g. Geoscience and Engineering (GSE) and Engineering Structures (ES). 3MD also uses the labs of ES for experiments on structural scale and, less frequent, the facilities of GSE. Also, in collaboration with other groups within the university, the acquisition of new high performance computing facilities started. Installation of these facilities (Delft High Performance Computing cluster) are planned late 2021. The department plays one of the leading roles in this initiative at university level.

10.3 Research and innovation: Developments since last research evaluation

10.3.1 Research themes based on societal challenges

Civil Engineering provides our society with solutions to major societal challenges related to climate change, energy transition, resource depletion and ongoing urbanisation (see faculty research agenda). In the 3MD department research efforts are focused on the themes *Climate change*, *Transition into renewable energy systems* and *Resource depletion*.

The construction industry has a major environmental impact. Production and processing of construction materials is energy consuming, resulting in a big CO₂ footprint as well as production of other harmful exhausts and waste materials and has therefore a strong negative impact on the environment. Furthermore, the volume of materials used is enormous, also having a significant impact via transport of construction materials. On the other hand, climate change itself has impact on our built environment. Within the theme *Climate change*, 3MD therefore defines two major sub-themes:

- Climate mitigation: 3MD contributes to this subtheme by development of durable and sustainable materials, smart technologies and circular construction strategies in order to reduce use of raw materials;
- Climate adaptation: by design and development of adaptive materials (smart, also 'bio-adaptive/receptive, nature-inclusive), constructions and integral strategies and solutions.

In this theme, 3MD follows a multi-scale and integral design approach:

- Materials/micro level, design of: self-healing materials, extending life-cycles of structures, high-strength materials, reducing volume of raw materials used, and innovative fabrication techniques, additive manufacturing. Also with respect to resource depletion, the department is working on topics as design of renewable construction materials, materials with improved recyclability, self-healing materials. For reducing CO₂ footprint, materials with low impact binders are developed, such as geopolymers that make use of waste materials or calcined-clay-based binders.
- Structures/meso level, design of: safe and reliable, climate-change proof infrastructure (e.g. houses, masonry quay walls etc.) through in-depth understanding of failure mechanisms in structures, but also related to sub-soil (e.g. soil subsidence), innovative numerical modelling of materials and structures, also using artificial intelligence (AI), and development and application of sensors for material health monitoring to ensure safe and low-maintenance structures. 3MD is also contributing to structural fragility and damage research for Groningen induced seismicity and other mining activities. We develop tiered analytical and computational models for masonry building response due to ground movements, calibrate them against multi-scale Stevin lab tests, and help authorities in making damage forecasts and decisions.
- Systems/macro level, design of: innovative integral design processes and adopting circular and sustainable solutions in infrastructures, smart ways to improve circularity within construction processes, innovative engineering asset management to extend the life cycle of infrastructure and reduce impact of maintenance and resilience of built infrastructure to natural and man-made hazards. On this scale, urbanization is an important theme, closely related to climate. The department is working on topics as multifunctional structures, integral design, climate adaptation, heat absorbing facades, green concrete (also climate change), low-impact construction technologies, adaptive and resilient built environment.

At different scales the 3MD department also contributes to the theme *transition to renewable energy systems* in two ways, by (i) multiscale design of (infra)structures for renewable energy systems, and (ii) design of energy generating and transmitting

materials and structures. Examples are at materials/micro level: self-healing pavements with electrical vehicle-charging capabilities, energy generating and harvesting (bituminous) pavements and structures; energy storing materials and elements making use of phase change materials (PCM's). At structures/meso level research is carried out towards the computational modelling of wind turbines, energy piles, geothermal energy systems and structural batteries.

Regarding the theme *resource depletion* in the 3MD department research is carried out on reduced use of materials through advanced design techniques for slender and light-weight composite structures, adaptable structures, materials and techniques for 3D-printing of structures with reduced material use and formwork, use of AI and numerical modelling tools to reduce use of materials, materials with improved recyclability, smart asset management and circular construction models from economic point of view.

3MD connects to major societal stakeholders as Rijkswaterstaat, Provinces and major engineering companies, in most cases on project level. However, more and more the department is growing towards an agenda setting approach, following the strengthening of the profile of the department along the multi-scale design lines and growing connections within the department. Members of the department are actively involved in committees and organizations like ACVG, Betonakkoord, CROW, IASS, KCAF, IABSE, VNConstructeurs, national Technical Committees of NEN, Netlipse, NVBV, Stutech and Stufib, and international committees of FIB, RILEM and ACI. In these committees research trends and findings are discussed with other researchers as well as future research needs and directions that are indicated by industry and government. A number of members of the department have part-time appointments at TU Delft and contracts with industrial partners. Through (guest) professorships 3MD has close connections with a number of international renowned academia like NTNU Trondheim, Ghent University, South China University of Technology and Southeast University (China). Apart from discussing trends and co-setting the research agenda's, 3MD also generates funding from these networks, illustrated by the solid contributions for the building response to induced seismicity research via NCG, IMG, NEN/NPR, NAM, Ministry BZK, Ministry EZK, ACVG, numerical impact studies funded by TNO, research on CE materials funded by Tata Steel, Province of Friesland and waste processing industry.

On national level, 3MD played a major role in a number of NWO-Perspective Programs:

- Geo-bio-civil: aiming to develop biology-based processes and products in order to substantially mitigate the pressure from the Geo & Civil Engineering activities on the environment;
- IS2C: aiming to encourage new technologies and innovations on durability and service-life assessment for the building and construction sector in general and for the infrastructure sector in particular;
- Enlighten: aiming at development of a scientifically proven design and production method aimed at producing large, reliable constructions with this material in a targeted, reproducible and cost-effective manner.

It is worth mentioning that for Groningen, the 3rd money stream is multiplied with TKI funding, a special funding for groups which acquired substantial industrial funding, towards healing the cracks and innovative strengthening techniques including structural glass/masonry concepts, with internal 3MD cooperation between AM and M&E and BE. The research is broadened to subsidence-induced building damage from climate change via the NWA granted LOSS-consortium, and to fundamentals for damage diagnosis and forensic engineering via IMG and Ministries.

10.3.2 Research strategy: environment for research to grow

3MD has strong competences in the following disciplines (as part of the faculty research agenda):

- Physics of materials;
- Mechanics of solids and structures,

and in the recent past 3MD also strengthened its competences regarding the integral design at structures and systems levels. As mentioned in the previous paragraph, in which we reviewed the recommendations by the assessment committee, a number of new positions have been created, providing opportunities to further strengthen the groups working on materials (assistant professor Materials Health Monitoring), and mechanics of solids and structures (assistant professors Robust-Nonlinear Computational Methods of Large-Scale Structures, Multi-Scale Modelling of Manufactured CE Materials and Mechanics of Nano-Structured Civil Engineering Materials). The new assistant professors are challenged to seek collaboration with other academics within the department or with other national and international colleagues. The relevant emerging technologies that are used and further developed are:

- monitoring, sensing and data;
- numerical modelling, simulation and design;
- risk analysis, uncertainty quantification, probabilistic design;
- smart materials and structures.

10.3.3 People and Community

Over the past years, 3MD never developed fully along lines of the PI-model, but strived to combine the more classic Rhineland-model, based on groups and group achievements, with the advantages of the Anglo-Saxon PI-model, aiming for individual excellence. Therefore, the hybrid policy of 3MD is to challenge all staff members to become an expert on their own field of expertise, but also permanently encouraging them to seek collaboration within the department or with other possible fruitful partners, both academic and in industry or government. With this strategy 3MD aims to build a group of scientific experts with firm connections within the department and strong national and international collaborations. The yearly research & development (R&D) cycle is an important instrument, also frequent bilateral meetings between senior and more junior staff members and other meetings are of importance in achieving these goals. For our assistant professors in a tenure track, the advice of the faculty Career Development Committee (CDC) is aligned with agreements made in the annual personal R&D meetings with the supervisor, in order to assure a smooth continuation of the development of the assistant professor. A basis for this personal development is their tenure track plan, in which they outline their scientific and personal development. Going abroad during their tenure track is promoted both for personal development and to encourage establishment of international connections.

With respect to inclusiveness and gender balance; the number of female faculty members was low. Substantial measures have been taken in the last years to increase the number of female colleagues, such as careful screening of advertisements in order to avoid a male bias, intensified use of (more and more available) female colleagues within the networks and specialized external recruitment companies. Over the past 2 years, 3 of the 8 vacant positions are taken by female academics; most likely leading to a gender balance of 9 male and 6 female assistant professors at the end of 2021.

The employee survey showed several employees reporting to have experienced undesirable behaviour, although not necessarily as a victim but rather as a witness. 3MD is determined to improve on this aspect. The topic was discussed in the board of the department, in the staff meetings and meetings of the respective groups in order to find causes of these relatively high numbers and possible solutions. Where more concrete information was available, section leaders and department chair applied case-by-case

measures. Together with HR and the TU Integrity Office next steps to improve are discussed.

PhDs are a large and special group of temporary group members, with the aim to finish their thesis work within 4 years. That is, however, seldom the case. In 2018, the board of the department agreed upon a set of measures to improve PhD yield, namely, (i) a stricter selection procedure, (ii) writing a research plan by the PhD shortly after the start of the project, (iii) a stricter go/no-go meeting, and (iv) carefully monitoring the final stage in which normally major delays occur. In all steps, the four-eye principle is applied. In order to give promoters the possibility to learn from each other's experiences, a bi-annual review is organized in which, in an open, critical, but confidential atmosphere, progress of the oldest cohorts of PhD's are discussed, but also the dilemma's and difficulties promoters are experiencing, as well as good practices. The group of 3MD-PhD's has active representatives in the CEG PhD Council, who are, although not participating in the board, connected to the management of the department by having direct links with department chair and executive secretary. Within groups there is regular contact, almost all groups organize colloquia on a regular basis. Since the outbreak of the Covid-19 pandemic, supervisors are making extra efforts to keep their PhD's connected, and in special cases, tailored solutions are provided. The department is also working on a buddy-network, which could evolve into a departmental PhD-council, in order to improve connections between PhD's and to try solving social issues.

10.4 Outlook

The 3MD research program for the coming five years focuses on societal and scientific relevance. The program is organized in a multiscale context with challenging topics within the three programs (M&E-micro, AM-meso, IDM-macro) and by means of well-defined connecting themes.

On materials/micro level, the group M&E will focus on the development of CE materials for additive manufacturing. Key points of attention are the use of green and sustainable binders, including fibre reinforcement to improve mechanical performance and the advanced use of sensors to enhance the production process. Furthermore, the development, testing and application of sensors is crucial for monitoring changes in material properties and performance. Sensor data are essential for prediction of durability and performance of structures and therefore for planning maintenance activities and with that availability of infrastructure. Primary goal of the group is to develop and valorise innovative high-performance, low-environmental-impact building materials and socio-environmental inclusive building strategies for improvement of wellbeing in the built environment.

On structures/meso level, the group AM will focus research efforts on the combination of computational mechanics techniques with state-of-the-art machine learning strategies for solving open issues in the design and characterization of complex, high-performance materials and structures. In the group efficient, accurate, reliable and robust models are developed for multi-scale temporal and spatial discretisation. With these models multi-scale deformation, damage and failure processes of advanced manufactured and traditional civil engineering materials will be analysed. The models will also be applied at larger-scale structural level in a parametric setting. Fast nonlinear solution procedures are integrated with structural monitoring techniques and structural design tools. In the structural design program of AM, safe, sustainable and smart strategies for the design and construction of civil engineering (infra-)structures will be developed with focus on e.g. structural glass, bio-based materials and parametric design/digital manufacturing. Regarding energy transition and climate adaptation, 3MD is expanding its research on

building response to ground movements. Within CEG 3MD develops cross-links with the Geo-departments for integrally studying deep soil + buildings including AI, and with Hydraulic Engineering for identifying hidden capacities in masonry city infrastructures like quay walls, societally relevant to cities like Amsterdam.

On systems/macro level a number of important research topics are defined in the IDM group. Resilience is selected as an integral theme with focus on integral asset planning and simulation models and service logistics techniques (e.g. mathematical programming, meta-modelling, machine learning, system dynamics, serious gaming and LCC/A engineering models), including the development of latest asset information and decision support systems technologies (including BIM). This research is performed in close cooperation with partners in industry and other scientific partners. Furthermore, the topic circularity is key with attention points as market potency and financial feasibility of sustainable innovations in the construction and infrastructure sector, spanning into various infrastructure assets, like wind parks, civil structures and buildings but also at the components (reusable materials) and material level (bio-concrete and potentially composites). Finally, research is focused on transdisciplinary design, i.e. the collaborative design with key players in the design process in order to realise joint and effective strategies that translate societal challenges in interdisciplinary design for infrastructures, and to contribute to designs, for instance for upcoming replacement of locks and flood defences, railway stations and (air)ports from perspective of upcoming transitions such as climate change, energy transition, circular economy and ongoing urbanisation. The research strategy is based on a combination of problem-seeking and problem-solving methods.

The topics within in the three groups are interconnected by the three previously mentioned themes (i) multiscale design, starting at manufactured material level (M&E) to computational multi-scale modelling (AM) to transdisciplinary level (IDM), (ii) circularity/sustainability with the development of circular/sustainable building materials (M&E) to the analysis of Total Cost for Society (IDM) and (iii) machine learning/digitalisation with the development AI techniques for material health monitoring (M&E, AM) and the resilience of structures (AM) and systems (IDM).

These common themes, together with the societal challenges, set the framework for recruitment of future staff members. This will further strengthen coherence of the department. Further improving the gender balance is aimed for by permanent embedment of the recruitment procedures from the recent past, namely : (i) by carefully screening profiles and vacancy texts on male bias, (ii) by making use of external networks or networks of female scientists in our current networks, and (iii) by using specialized external recruiters. For its staff members, 3MD is going to emphasize in the yearly R&D meetings more on development than on past performance. For our young staff members, the R&D-meeting will be clearer lined up with TT-policy to meet development goals necessary for passing the CDC-criteria in order to become tenured staff. For tenured staff, emphasizing development and carry out "on-track" analyses is essential to enable academic growth, to organize involvement and embedment in the department and to motivate staff members for future societal and scientific challenges.

