Research Assessment Exercise (RAE)

Panel 1: the School of Architecture and the Built Environment

Coordinator: Mats Wilhelmsson

Long version

Stockholm, 2020-04-30

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PART A: Summary

0a. Description of the field of departments included in the panel

Introduction

The Architecture and the Built Environment panel consist of the following six departments:

- Architecture
- Civil and Architectural Engineering
- Philosophy and History
- Real Estate and Construction Management
- Sustainable Development, Environmental Science and Engineering (SEED)
- Urban Planning and Environment

The overall vision of the School of Architecture and the Built Environment is to develop sustainable solutions to societal challenges. This applies to education as well as to research and in collaboration with society. Within research, the goal is state-of-the-art research but also research that is visible and makes a difference. This means, among other things, that the school is working systematically with the global sustainability goals and ultimately to increase its ranking. To accomplish this, the school collaborate both nationally and internationally.

Important indicators for the school's forward-looking development process includes placements in various rankings such as Academic Ranking of World Universities (ARWU) and Quacquarelli Symonds (QS) ranking. More directly, the school also use indicators such as the number of publications to internal and external research funding, as well as the degree of citation and publications within the Sustainable Development Goals (SDG) area.

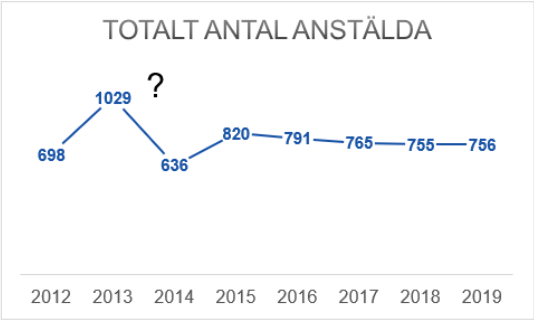
The Panel in Numbers

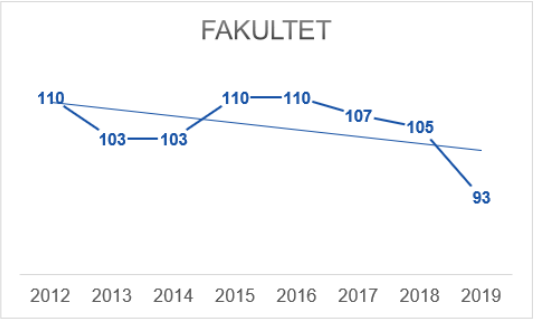
The panel's operations will be described based on the number of employees and research funding that constitute input into the research process. As output, the research will be specified based on doctoral degrees in research education and publications.

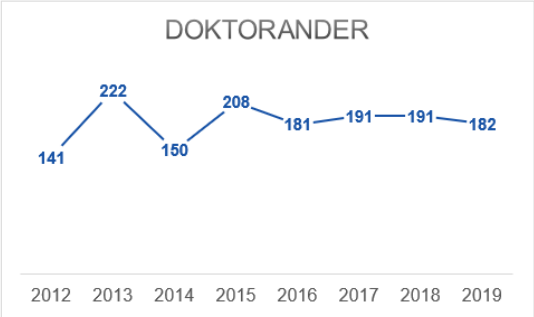
Input: Employment

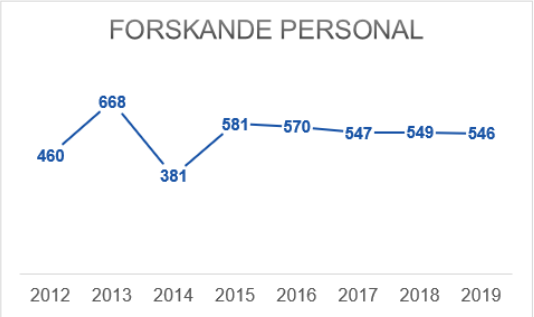
The total number of employees at the school is approximately 750 (see figure below), counting the number of heads (based on full-time equivalents, it is about 450 employees). Of the 750 employees, about 100 are faculty members (professors and assistant/associated professors), and about 200 are doctoral students. In total, the research staff makes up to about 550 employees (about 75 percent of the total number of employees). The remainder of the employees is administrative personnel and teachers purely in education. However, among the research staff and faculty, a significant amount of teaching also takes place. The trend in recent years has been that the number of employees in the faculty has

fallen somewhat. The reason behind this, among other things, has been retirement and that the school has been unable to recruit new faculty as a replacement.

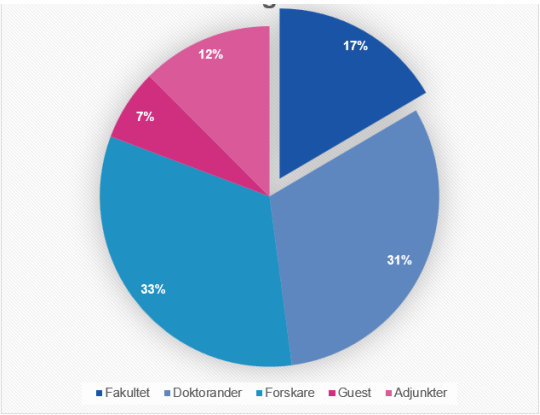


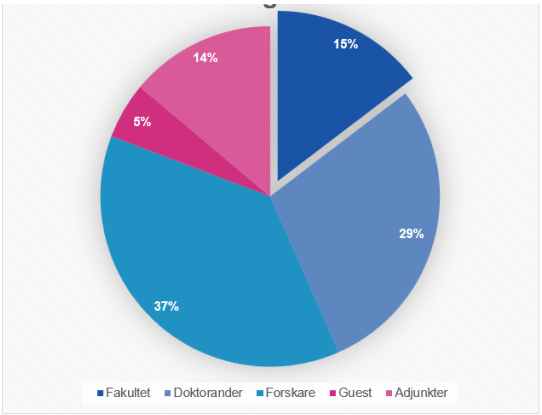






The number of doctoral students and research staff has been relatively consistent in recent years. What is apparent is that the number within the faculty group has fallen. In 2015, the share of faculty out of the total number of employees was approximately 17 percent (see figure below). That share fell to 15 percent in 2019.

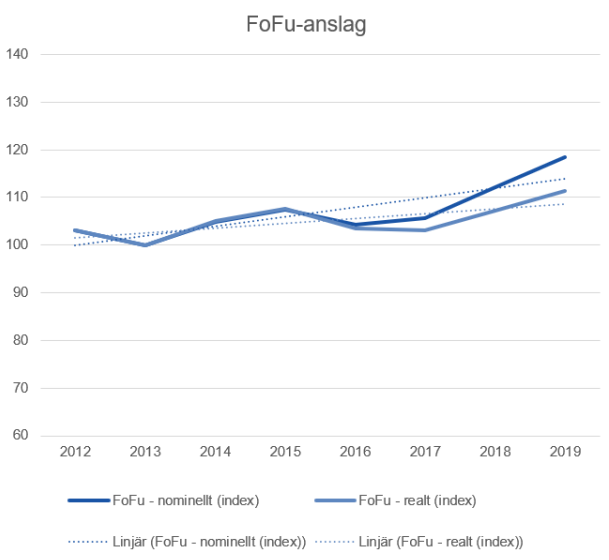


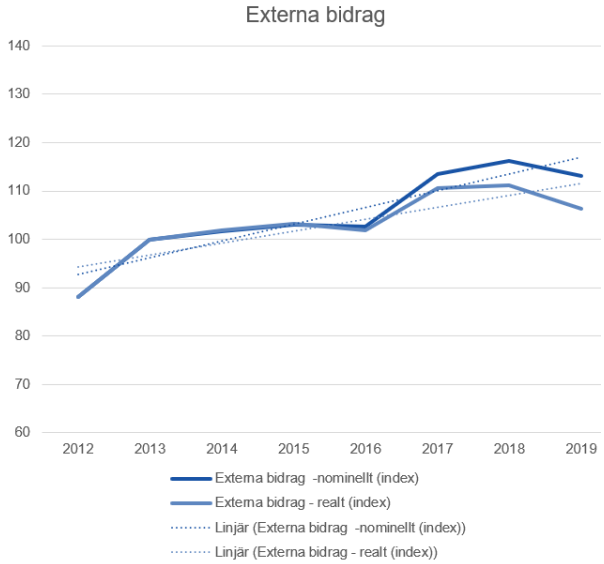


There are some problems with the statistics. The number of employees has been, in some cases, double-counted when a reorganization has taken place. Moreover, some occupational categories are missing for the entire period. Both of these problems make the interpretation of the statistics more complicated, especially when comparing between departments in the panel and over time.

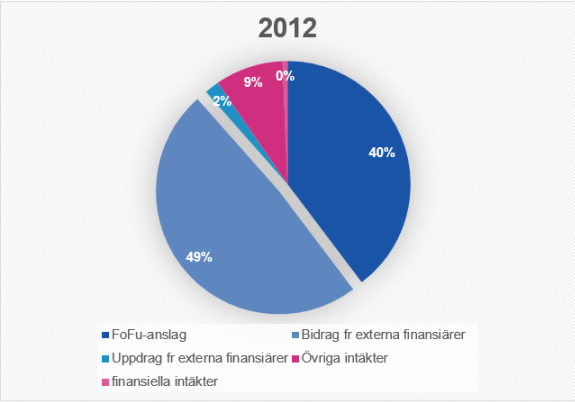
Input: Research funding

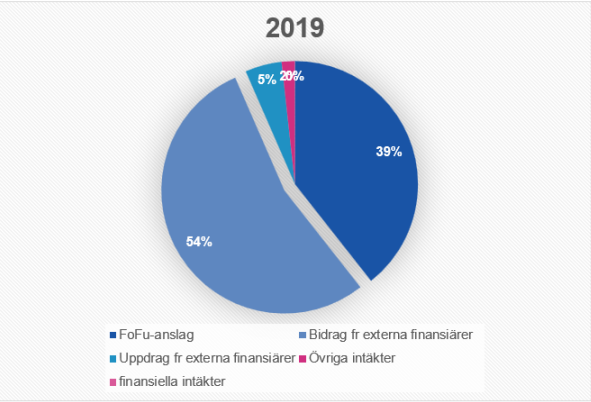
Total internal and external research revenues have risen over the years, both nominally and in real terms (see figure below). Even if the trend is upward, it can be noted that the trend has been somewhat more definite when it comes to obtaining external research funding than internal. Internal research grants have increased, but its share of the total research revenues has been stable over the years (approximately 40 percent).





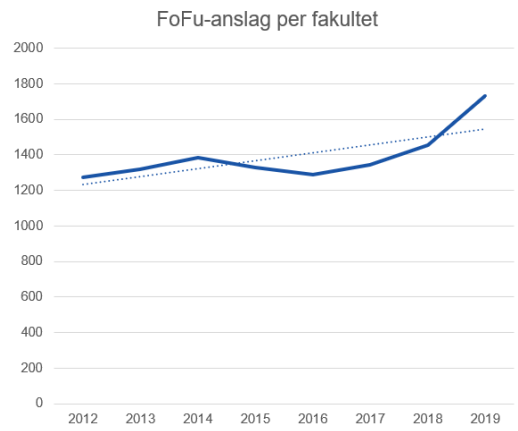
External research funding had increased slightly from 49 percent in 2012 to about 54 percent in 2019. Thus, the school's dependence on attracting external funding has increased. As a consequence, the proportion of short projects has risen. The school's most critical external financiers are the public sector (national research funds and EU funds).

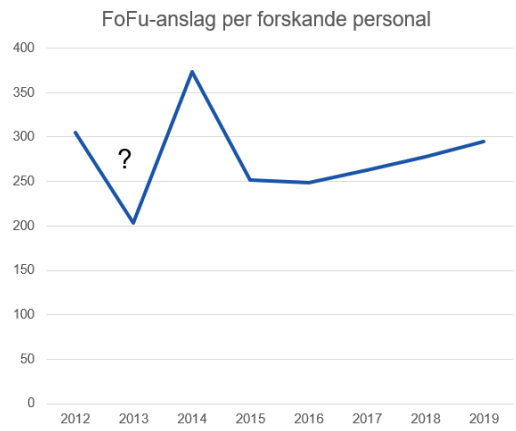




In summary, the research funding has increased slightly over the years while the number of staff has been relatively consistent. As the proportion within the faculty has dropped, both the internal and the external research funding have increased per faculty as well as per research staff (see figure below).

This can be regarded as something good, but it is a result of a smaller faculty. Moreover, it is not sustainable as the school's teaching mission is still the same.

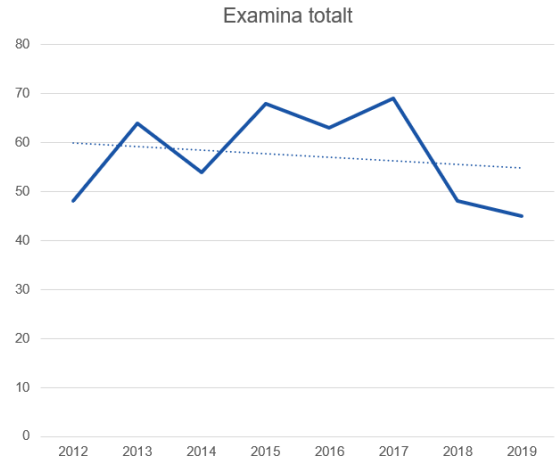


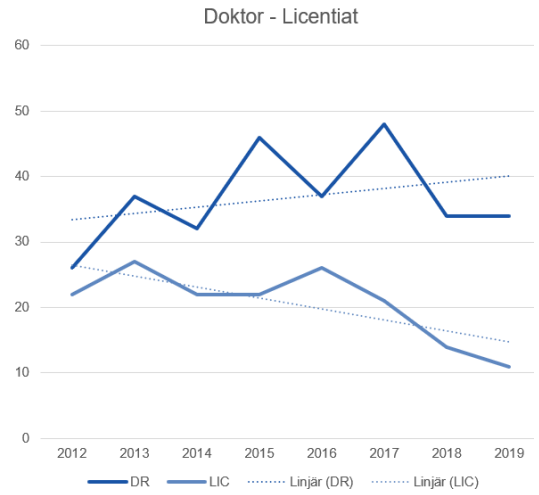


There are some minor problems with these statistics. It may be difficult to compare the statistics to the number of employees, but this is more due to a lack of certainty regarding the number of employees. For instance, the statistics can be challenging to interpret in cases where there has been a reorganization.

Output: Examines

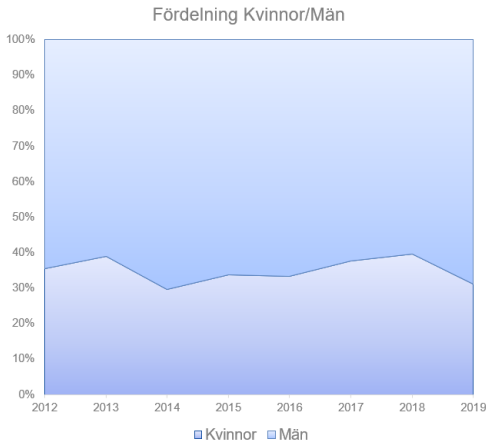
An essential output in the research activities is the degrees in postgraduate education. A large proportion of research is conducted within the school's doctoral projects. What can be observed is that the trend for the total number of degrees has fallen. It is the number of licentiate degrees that has dropped over the years while the number of doctoral degrees has increased.





This is a worrying development as the doctoral degrees of the future are a projection of the licentiate degrees. One contributing reason may be that it has become increasingly difficult to fund doctoral students for four years. However, it may also be that there has been a trend where more and more of the

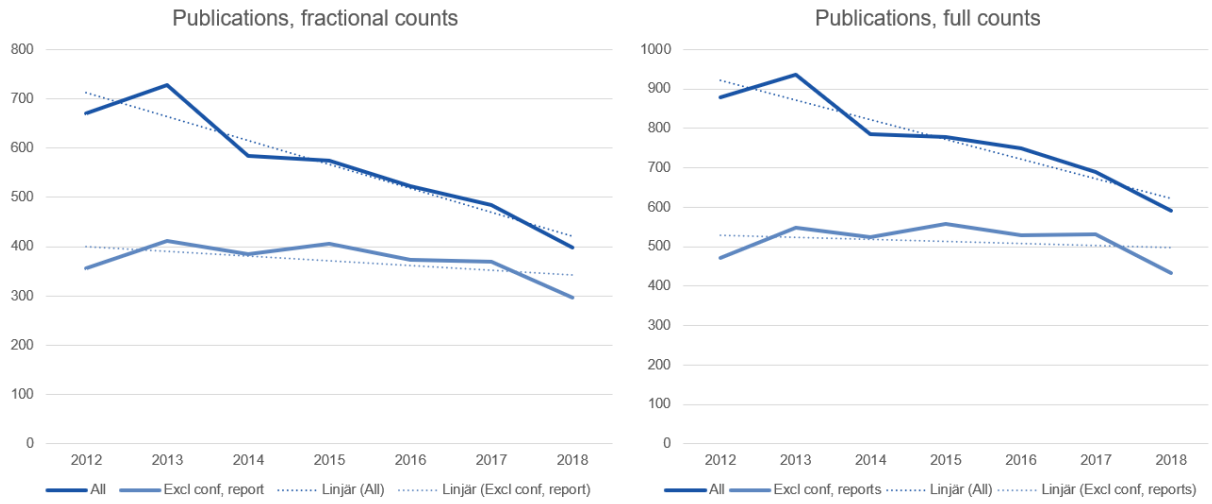
doctoral students are aiming for a doctorate instead of taken the licentiate degree. Although the degrees have declined somewhat over time, the number of degrees per faculty has been constant. When it comes to the proportion of women among the school's PhDs, it has remained steady at the level of 30-40 percent in recent years (see figure below).



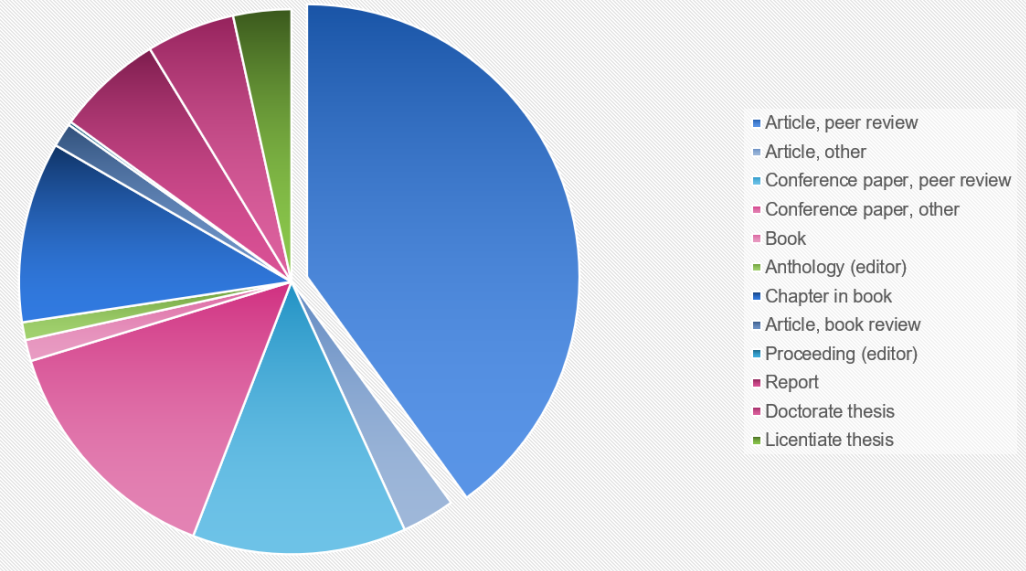
When looking at the statistics regarding doctoral degrees, it can be noted that there are significant problems in terms of organizational affiliation. It is still possible to analyze on an aggregate level but this makes the analysis within and between the departments more difficult.

Output: Publications

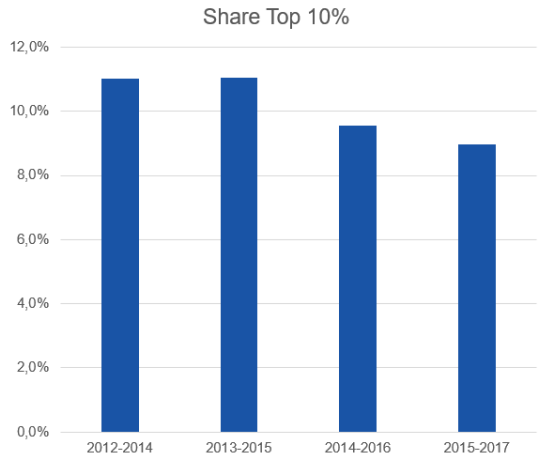
The trend has been that the total number of publications has decreased during the period 2012 and 2018 (see figure below). What has mainly declined is conference contributions and various types of reports in Swedish and English. The trend concerning peer-review articles has been somewhat negative over the years but has mostly been around 500 publications (full counts) per year.

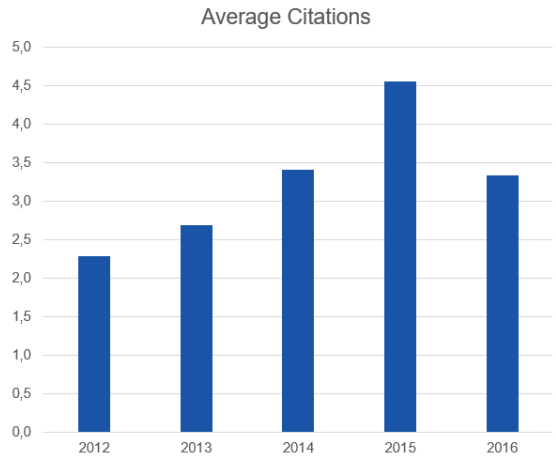


Of the total number of publications, articles in international journals account for about 40 percent of the publications over the entire period. Conference contributions and anthologies have also been essential outputs for the school's research (see figure below).



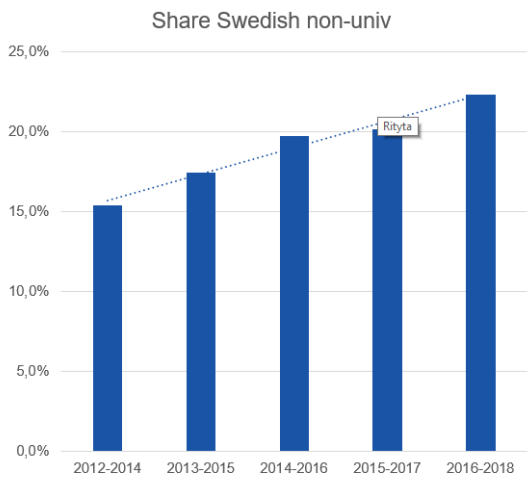
The proportion of articles published in the top 10 percent of journals is relatively few (only around 10 percent), and the proportion has decreased over time (see figure below). One reason may be that many of the journals where the school has published its research are relatively new in the area of sustainability and not so well established yet that they belong to the top 10 percent of the journals. The average number of citations to published articles has increased over the period 2012-2015. The fall in 2016 is natural, as citations always occur with a delay. Articles published in 2016 will undoubtedly receive more quotations in the future.

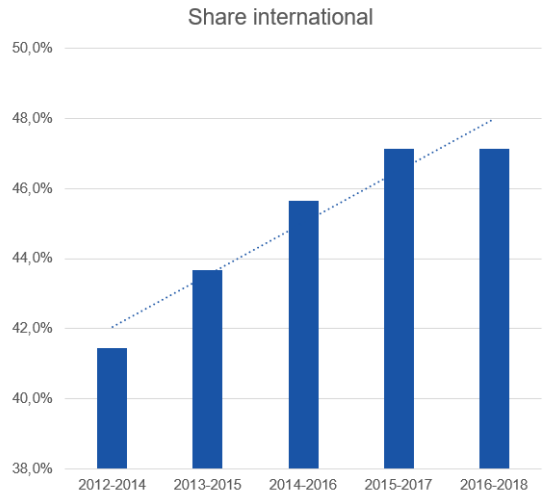




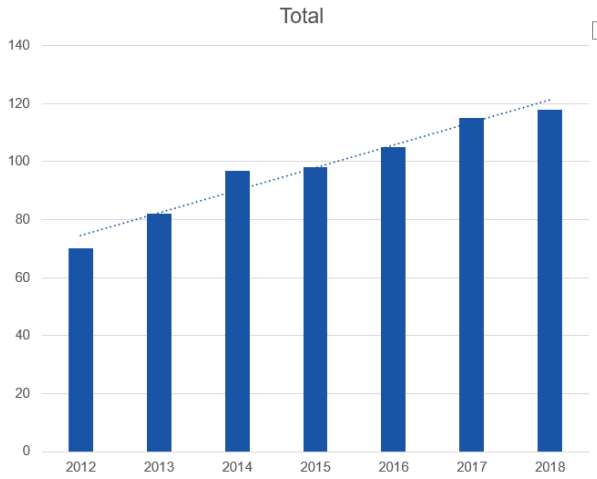
Two strong trends that can be observed are that the school collaborate much more often in research projects and publications. The co-authored publications are increasing over time both when the school is collaborating with Swedish non-university authors and researchers internationally. Around 45 percent

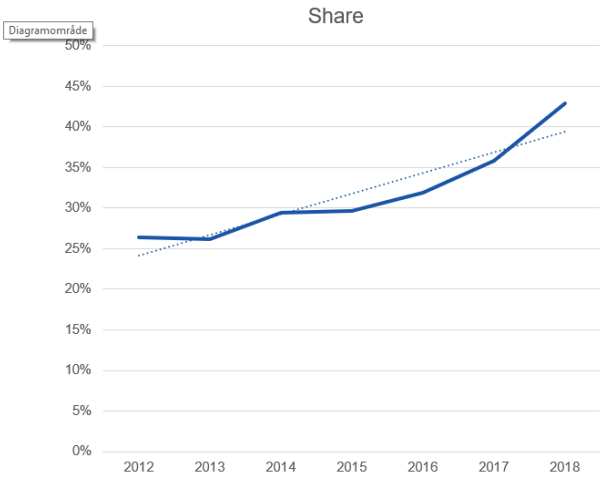
of the articles that are published take place with colleagues around the world (see figure below). The number of publications per faculty or research funding has been at a constant level in recent years.





The number of publications with a clear sustainability profile has increased in recent years (see figure below). Of course, it is both that the marketing has improved and as well as that the research has an increased sustainability perspective. We can see that the proportion of our publications in international journals with a SDG marking has increased from just over 25 percent in 2012 to almost 45 percent in 2018.





When it comes to the statistics on publications, the statistics addressed is where the researchers have the greatest knowledge. If all publications are included, if it is measured correctly, if all journals are included, are questions that create many thoughts. It can be noted that not all articles published by researchers within the panel are included. There are various reasons for this, and some departments are more affected than others are. One example of an obvious shortcoming is that publications from employees who have previously been employed at research centers (within the panel) are not included. A systematic effort to improve the bibliometric is welcomed.

0b. Description of the self-evaluation process for the panel

Here it is described how the coordinator has organized the work together with the departments to complete this self-evaluation report.

Work process

The work with RAE began in January 2020. The organization around the work at the school level has consisted of the coordinator with administrative support together with the heads of the departments and the school management. On January 15, a workshop was organized to review and discuss the self-evaluation template that was sent out the same day. The discussion was mostly about the layout of the template, and comments were made that it would be short of time to finish the self-evaluation by mid-March and that the panel should have had the possibility to review the template at an earlier stage. The positive part of the workshop was that, early in the process, the coordinator had ensured that all the heads of the departments had read the self-evaluation template.

The coordinator's schedule for the work was also presented. This involved the work of proposing external experts to the panel and the work on the panel's joint self-evaluation. The work of coming up with potential experts for the panel was carried out by having the heads of the departments propose a number of experts of both genders. After some coordination work, some of these proposals were sent to the project team at KTH. Early on, the school receive a number of positive responses. Unfortunately, at first there was a gender imbalance in the panel of experts. Further suggestions with names were thus female experts in the field. After a discussion with the heads of the departments, it was proposed that the group of external experts was expanded to 13. This decision was taken to get the broadest possible dissemination of scientific subjects within the panel.

The external panel of experts consists of:

- *Architecture*
  Murray Fraser (London)
  Eeva-Lisa Pelkonen (Yale)
- *Urban Planning and Environment*
  Graham Haughton (Manchester)
  TBA
- *SEED*
  Thomas Christensen (DTU, Denmark)
  Stefanie Hellweg (ETH Zurich)
- *Philosophy and History*
  Alfred Nordmann (Darmstadt)
- *Real Estate and Construction Management*

Alison Kealy (RMIT, Australia)

Nancy Wallace (Berkeley)

- *Civil and Architectural Engineering*

  Jarek Kurnitski (Tallinn)

  Eleni Chatzi (ETH Zurich)

- Industri/samhällsrepresentant

  Dag Björklund (Samhällsbyggarna)

  Ulla Bergström (White arkitekter)

According to the timetable, the first version of the panel's self-evaluation would be completed by mid-March. From mid-January to mid-February, work would be done at each department. At the end of February, an internal conference was organized with the focus on the work with RAE. During the interim period, two reconciliation meetings were held between the heads of the departments and the coordinator. The conference's purpose was to gain a consensus on what should be included in the self-evaluation and to gain inspiration for the continued work. The internal conference had three main themes, namely (1) discussing impact cases, (2) a strength and weakness analysis, and (3) presenting and discussing the background statistics that were sent out the same day.

The organization of the work at the various departments has been very different. Some have had a more explicit bottom-up approach, while others have had a more top-down approach. Those with a more bottom-up approach may have involved more of the employees in their work with the self-evaluations. Regardless of the approach, most of the departments have conducted surveys for all employees and/or for the faculty alone. All departments have had one or more group discussions and seminars on the work with the self-evaluations. It is the assessment of the coordinator that those who have wanted to comment and be involved have had the opportunity to do so.

The coordinator also held a workshop with the school's strategic advisory board, with a particular focus on the cooperation aspect.

At the beginning of March, the conditions changed utterly. In principle, all work with RAE was put into the process of switching to distance education and with organizing that the employees were able to work from their homes. The assessment, as coordinator, was that there was neither time, resources, nor commitment to complete the department's self-evaluations at this time. KTH also had a clear focus on prioritizing education.

The first version of the panel's self-evaluation would consist solely of the respective department's self-evaluations. The idea was that the coordinator would begin the work of writing the summary in mid-March to mid-April. When the decision that RAE was moved forward one year, the work on the self-

evaluation in the organization had been discontinued for about two weeks. The coordinator decided that the version to be submitted by the panel at the end of April, for internal review, would consist of the summary text written by the coordinator. The departments' self-assessments, in some cases not finished, would be used as a basis for the panel's self-evaluation report, but they would not fully be included to the report.

0c. Identified panel synergies

In this section, the synergies and common challenges identified within the panel are described. First, the strength and weakness analysis will be presented. It is based on the workshop that was held in February 2020 and documents from the departments' self-evaluations. Secondly, a reflection from RAE 2012 is presented. Furthermore, an executive summary of all departments' self-evaluations and a written text by the coordinator will be presented.

The strength and weakness (S/W) analysis

The SW part of the SWOT analysis was carried out at each department and at the internal conference organized in the panel. There is a relatively broad consensus in terms of both strengths and weaknesses despite the substantial differences in research volume and research orientation at the various departments and even within the departments.

Strengths

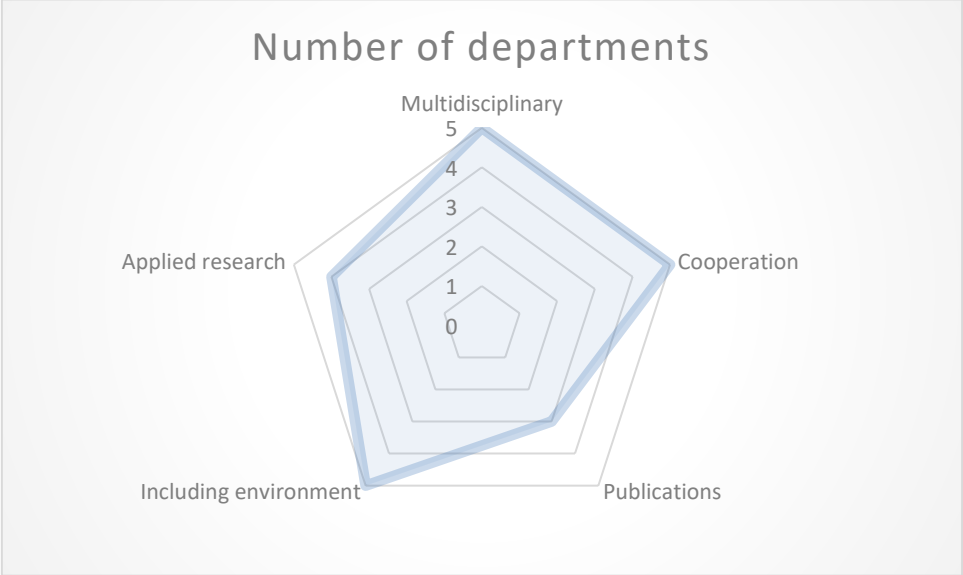
The strengths pointed out from many research environments are that they have a strong connection to the industry and the societal sector. In principle, all departments mention it as one of their strengths, together with the fact that research is mostly problem- and challenge-driven, which leads to high social relevance. It also means that many researchers at the various departments are visible in the social debate.

Many of the departments also raised its multidisciplinary environment as one of their strengths. Several departments also mention that their research environment is inclusive and has a satisfactory gender balance, and this contributes significantly to their research strength. Most also express that their national and international networks and collaborations are important strengths of individual researchers but also in the research environment.

A few departments also mention the increased publishing rate, a good publishing tradition and an increased focus on a better publishing strategy that has strengthened the research environment. The challenge-driven research environment has high societal relevance and has meant that the research profile towards sustainability in all its dimensions has developed the research environment and made it

more competitive. Several departments also point out that it has attracted large research grants, which indicates a research environment with many strengths.

Some have also raised the link to undergraduate education as one of their strengths, i.e., research provides valuable inputs to the teaching. Moreover, in other departments, the students also play an important role in the research through their master thesis work.



One reflection that can be made is that many strengths in research and the research environment within the Architecture and the Built Environment panel are similar. The research environment is perceived as multidisciplinary with good cooperation nationally and internationally, and research has high societal relevance. In most cases, the physical and social work environment is something that is, in general, satisfactory. Above all, it is perceived as inclusive with a generous research climate.

Many of the strengths of the research environment are factors that must continuously be developed and improved. Which of them is strategically the most important, or should resources be allocated to all of them? The question is, if strengths can be compared to one another, is collaboration more important than any of the other strengths? Probably not, all are related and are essential factors for creating a thriving research environment.

Weaknesses

Of course, the analysis of weaknesses is of greater interest as it has a potential impact on proposals for measures to improve the research environment. Undeniably, research funding is of great importance in order to achieve high-quality research. There are opinions that the school is too dependent on external funding. While this does lead to research being of high societal relevance, it also leads to some research being rejected. The requirements for counter-financing, both in the form of co-financing from KTH but also from the industry, are perceived as a weakness. The search for research funding also means that the

school often compete with other researchers in the organization. One weakness is that the school has not been particularly successful in applying for and obtaining EU funding.

With a great deal of external research funding, in many cases, research becomes short-term. Long-term financing is difficult to obtain. It also makes it challenging to allocate funding for doctoral projects. An apparent weakness in recent years has been the decline in the number of postgraduate students.

A large part of the panel's operations has been built with external research funding. This has been made possible, as it has been identified as important research areas both internally and above all from the surrounding community. One weakness then has been that although the school has been able to increase the volume of research, it has not been able to translate it into new faculty positions. Instead, researchers have been recruited (non-faculty positions). This has led to an imbalance between faculty and non-faculty positions at the departments. Some departments feel that they have not got a large enough faculty to get a good mix of research and education. The school also has received an increased mission when it comes to education. An ever-smaller faculty then had to handle the increased teaching volume, while researchers and postgraduate students have increasingly done the research. For example, some research environments point to shortcomings such as too little senior research done by the faculty.

Another weakness that some departments have addressed is the issue of an ongoing generational shift. Some have just been through a generational shift, while others have it ahead of them. Here, of course, the faculty renewal plans are essential as a basis for this generation shift, but the problem is the lack of internal research funding. In many cases, there is a system that makes it impossible to recruit new faculty even when some of the existing faculty is going into retirement. This difficulty is particularly problematic in small research environments. Another dimension of the generation shift is that relevant networks may be lost.

All of the departments address the weakness of the imbalance between research and education. Some environments have a considerable amount of teaching, while others have relatively more research. Those who have much research find it difficult to get more teaching, and those who have considerable more teaching find it challenging to obtain an increased research volume. A large part of the faculty feels that it is difficult for them, or that they do not have the opportunity, to spend time on either research or seeking research funding.

One other weakness that is addressed by many departments is the small research groups. There is a risk that in certain areas, the research will not reach a critical mass. Even though the school is relatively large, it is fragmented in small research environments within many different science disciplines. There is a tendency for these groups to be solitary and have relatively little contact with other groups within the department or at other departments. Research infrastructures are also addressed as a weakness in some research environments.

In a few departments, certain work-related problems exist with a weak group identity, together with a lack of internal cooperation. These issues have been identified in the RAE process and are currently being addressed.

One reflection that can be drawn is that a large part of what is discussed as weaknesses are issues that cannot easily be addressed within the panel or the school. This relates to the issue of, for example, the relationship between internal and external research funding. Other weaknesses, on the other hand, are issues that are either within the school's area of responsibility or even within the department's area of responsibility. This concern, for instance, how to allocate resources to build a world-leading infrastructure within the area of expertise or how activities with small research groups can be supported.

Reflection from RAE 2012

In RAE 2012, several recommendations were made at a general KTH level and other more specific recommendations to departments and research groups. At a general level, KTH was recommended focusing more on recruiting excellent staff and focus resources on the research of the highest international level. Moreover, KTH was recommended on working with strengthening the already good networks with the surrounding community and ensuring that resources are devoted to instruments, equipment and infrastructure of the highest quality. Finally, KTH was recommended to continue to communicate its strengths in research to a broader audience.

All of these recommendations are largely incorporated into the School of Architecture and the Built Environment’s work on the long-term research strategy development. This is especially true when it comes to the work of recruiting future faculty. Of course, the school strive for research that is at the highest international level, and resources are allocated to have the greatest societal impact possible. Communicating the research has been, and is, a priority area for all research groups within the panel. This is especially important in an area that deals with applied research that is vital for sustainable societal development.

What the school may have missed, but which has recently been given a greater focus, is the work with the infrastructure. Here, the intention in the coming years is to develop the already existing physical infrastructure but also to develop the digital laboratory infrastructure for both research and education. This also includes ensuring that more social science research has access to data. In this context, the school’s recently initiated collaboration with MIT and the City of Stockholm can be mentioned as a result of this effort.

The more specific recommendations at the department level followed the present organizational structure at the time. Here, changes have been made in accordance with RAE 2012's recommendations. The departments *Land and Water Resource Engineering* and *Industrial Ecology* have now formed a new department together with parts of the department *Urban Planning and the Built Environment*. This has

been done to focus the resources and to get a better organizational structure to promote sustainability research. Other research environments got recommendations to strengthen the research profile, to review new faculty recruitment, to handle generational shifts early, and to pool research resources by creating new research centers. Since RAE 2012, two new research centers have been developed in accordance with the recommendations given, namely the *Water Center* and the *Center for Building Efficiency*.

Part B

As the RAE 2020 process was halted as a result of COVID-19, not all self-evaluations were completed in March. The panel coordinator decided that the heads of the six departments should focus on the educational mission. The structure of Part B follows the self-evaluation template, even if not all parts will be included. Part B is based on, in some cases, completed self-evaluations from the departments, in other cases, a gross list of content that has been discussed at the department level but which has not yet been analyzed and discussed. Part B is entirely the coordinator's selection of materials and may not represent the view of the department.

Research Assessment Exercise (RAE)

PART B: The self-assessments at the department level

Department of Architecture

1. Overall analysis and conclusion; Strength and development areas

Strengths

Research

- Collaborations and networks
- Strong integration between 'applied' and 'base' or 'theoretical' research
- Output *quality*
- Integration/discussion with other research directions; openness to initiatives/interests across directions
- Societal relevance (as evidenced)
- Short/short-term funding in applied research growing to longer and more cohesive projects
- Cooperation within ABE
- Diversity of publication & dissemination forms and channels (roles as editors, etc.)

Organization

- Doctoral program as integrated and integrating activity (good for both doctoral students and general research integration)
- Potential to pursue interests and opportunities that emerge (individuality and independence in research) (see also threats)
- A clear formulation of research profiles to help focus within the wide and complex subject

Weaknesses

Research

- Funding balance
- Applied funding often short projects / short-term
- Staffing
- Information structure
- A profession that is slow at integrating research and researchers

Organization

- Implementation/Integration in/with education
- Barriers to expanding/grow
- Staffing as a slow, complicated process that at the same time is unpredictable
- Research environment

- Support for team spirit/work for common interest, including explicit tasks, participation in common academic concerns, engagement in external but important academic networks and collaboration
- Administrative support for research
- Support with applications
- Underdeveloped procedures and forms, Urban design is a 'hot' topic, which offers potentials for interest, collaborations and funding

2. Research profile

The Department of Architecture at KTH is one of six departments that makes up the School of Architecture and the Built Environment (ABE). The Department of Architecture at KTH produces education and research in architecture and urban design. It is one of four schools in Sweden, which educates architects. The Department has approximately 550 students in basic and advanced levels of education. It runs a five-year professional program in Architecture, a two-year M.Sc. in Architecture, a one-year program in Lighting Design, and shares the responsibility within ABE for the cross-departmental M.Sc. program Sustainable Urban Studies and Design. On a doctorate level, the Department runs two PhD-programs; in Architecture and in Art, Technology and Design.

Research within the Department of Architecture seeks to provide analytical and projective perspectives on the history, development and future of the built environment and of the architectural profession in terms of technology, culture, criticism and aesthetics. The Department of Architecture conducts research within areas of urban and applied urban studies, housing and building technology, gender and equality studies, welfare studies, history and theory as well as design research. A current focus is on welfare studies relating to both deregulation of institutional organizations as well as the social impact of integration and gender equality and applied urban and housing design. Another venue of research is the integration of material technology and design, as well as transdisciplinary studies of the built environment with regards to sustainability. A particular focus in this area is lighting design.

Across recent years research has been sustained by five research groupings that provide both investigative breadth and depth of focus. These research groupings are Architectural Technology (AT), Architectural Design (AD), History and Theory of Architecture (HTA), Critical Studies in Architecture (CSA) and Urban Design (UD). Over the past ten years, these research fields have had notable improvements in the quality and visibility of research produced and through strong faculty staff and doctorial students. In particular, the work of the applied urban design group and the architectural history and theory group in relation to welfare state architecture and to feminist critique has become internationally renowned and is of extremely high quality. What made up the foundation for these

research fields have transitioned into other areas of research, which are developing but have not yet reached the international standard that earlier research groupings have produced.

The new constellation of research members is broadly categorized under three main research areas: Architectural Design and Technology, Urban Design, and Theory, History, and Critical Studies in Architecture. However, research within the Department of Architecture is very fluid in terms of how researchers collaborate and what constellations make up a research team. This is a specific strength that relates to a few organizational circumstances within the Department. Firstly, course teaching has across the past couple of years been loosened up in the core courses as well as in-studio teaching, i.e. courses have been redistributed among faculty. Secondly, the Department practice collegial teaching, which means that a) there is not a professor-assistant relationship in course teaching, but two individuals collaborative teaching in xx out of xx courses, and b) there is more presence of researching staff in the core courses and studios as of 2018. Thirdly, the Department is not organized in subcategories either financially nor in terms of facilities. Instead, the Department uses the above-mentioned fields in order to communicate research rather than categorize individuals to a field and, in addition, work with an internal structure related to teaching, year by year. In effect, it means that research/teaching staff in history, theory, technology and design across one year is one set of belonging, and the research fields are another set of belonging. This perhaps communicates ambiguity in relation to other departments at KTH but has strengthened the Department within.

Central research questions within the Department are welfare studies and questions of urban development and public culture, as well as historical and theoretical shifts of welfare spaces and policies; Architecture and urban design explored through feminist theories and practices; and Building technology explored through critique using representation, digital methods of fabrication and code.

The following knowledge gaps have been identified and addressed in the research activities within the field/profile over the last five years.

(1) Architecture may be used as a conceptual lens to investigate complex socio-historical processes of spatial production, while also providing a concrete means to intervene in these processes. Architectural research may thus contribute to a more nuanced and complex understanding of social transformation and by foregrounding the significance of material space in shaping and organizing communities. The intellectual outset for such investigations needs to be more firmly established by incorporating key aspects from, e.g. capitalism studies, ecological complexity thinking, environmental humanities, contemporary archaeology and material culture studies. That is to say, there is no lack of knowledge, but it is very important to identify which strands that need to be tied together in order to establish a strong platform that brings specific problems and methods into view.

(2) There is a lack of methods and methodology for contemporary history research and urban and regional analysis. The identification and exploration of 'good practice cases' of 'critical spatial practices' that address questions of equality, diversity and inclusion of which there is a lack of records and systematic discussion of their contributions to social sustainability.

(3) Modeling for morphological analysis, while established and useful in practice and research, needs refinement both theoretically and in modeling practice. It needs to integrate with a wider set of modeling theory and to be critically examined as relates to subjectivity, diversity and modeling intent and implications as well as in relation to empirical data. Closely linked to modeling is computer's current role in architecture were looking at code allows addressing some aspect of what Gilbert Simondon defined as the "technicity" of the computer, a quality which would temper claims linked to its possibilities, as well as affording precision to its criticism

(4) Research primarily contributes to an increased understanding of the relation between urban form and urban processes. It bridges academia and practice, and methods and approaches are refined/modified to be easier to apply and use for practitioners. It includes how to use and handle digital data in modeling and spatial analysis.

(5) Without broad reinforcements of competence, a fast escalation of house building, necessary for reaching this goal, might lead to long terms negative effects such as poorer house standards, greater segregation, and negative climate and environmental impacts. This demonstrates the prime importance that society join forces by developing inclusive and efficient urban development processes. There is a strong need to involve more and new actors and citizens in early planning phases. This puts high demands on competence for leading these integrated processes aiming for creating a multitude of co-created initiatives.

Main contributions are among other things:

(1) Critically assessing spatial production and aesthetics within a framework of political philosophy in order to explore the multidimensional aspects of public space in relation to notions of democracy; Critically assessing the construction of the discipline through a close engagement with concepts and methods in the arts and the humanities, which also exposes the unique capacity of architecture as a way of looking, understanding and doing

(2) Development of methods for collective and participatory action research; interdisciplinary progression of research that applies both architectural and ethnographic approaches such as visualization, semi-structured interviews, and academic publishing but also public performative and other art-based research methods; the production of numerous public events and exhibitions.

(3) Theory and method development concerning (spatial) modeling for critical analysis and design work, including relations between specific questions, model specificity, and diverse and situated subjectivity; integrated with the development of methods and tools for modeling space and engaging with challenges and shortcomings of concurrent empirical research in spatial analysis in the

architecture field as well as societal challenges such as segregation, power, and unequal living conditions.

(4) New methods and approaches related, for example, to opportunities in a city and theoretical development of how architecture is seen as built spatial structures relate to social and political processes. Including methodological development, how to gather, organize, and structure data that makes it possible to use and integrate into spatial and configurative analyses. Especially concerning the urgent challenges of segregation and unjust living conditions.

(5) Models for process governance of urban development project, today implemented in SGBC CityLab. The model itself is innovative, but most of all, foster innovation, supporting the development of new innovations in local conditions, always dependent on, e.g., economic, social, organizational, or environmental factor.

(6) Putting forth a methodological platform for academic writing that experiments with and transgresses conventional norms and borders, as based on the "ecological thinking" and "transcendental empiricism" of Gilles Deleuze and Félix Guattari.

3. Viability

Research in the Department of architecture consists of 26% of the total revenue, which can be divided into 11% FoFu (state-funded research and research education) and 15% external finance as a result of research applications. The largest providers of research funding are Vinnova, European framework, and program for research and innovation such as Horizon 2020, Bertil and Berit Svensson foundation for lighting, FORMAS, Arwidsson foundation, and the Swedish Research Council. Most financiers support co-financed projects and are based on collaborations with other actors in society. In addition, societal relations are important for the kind of innovation-driven research that is part of our agenda. The collaborative aspect of research in the intersection of societal needs, innovation design, and academia is very important for the progression of our research and educational output. Co-financed research also guarantees a large societal network, which is important for both advancing existing research as well as improving practice-based research.

Strategically, it important to strengthen academic research as well as research by design and practice-based research. Co-financed research and innovation-driven research has expanded in recent years, while "basic" research and research concerning theory methodology has decreased somewhat. However, with regards to the scope of research projects, size, and financial support through external funding have increased over a ten-year period, which is a positive direction for the Department.

Within the urban design and applied urban design a number of wide-spanning research projects that have engaged a large number of societal actors such as municipalities and other state authorities understanding the relation between urban form and urban processes, e.g., power relations, segregation

and conditions for economic investment, has required co-financing for which funds have been granted from the ABE-school in order to cover these costs. In general, for these kinds of research projects, there is a high requirement for co-financing in order to allocate external funding for these kinds of research projects. This is one of the aspects to consider in the evaluation of the distribution of funds towards research at the Department. On the other hand, this wide-spanning research will have a strong effect on society as a consequence of its organization.

Architecture as an inclusive field of research has a great potential to develop through collaboration with other disciplines and which the Department is working towards developing strategies for. In this regard, we continue to have ongoing discussions about applications and how to improve our routines and support systems. The Department has started to organize application seminars as the first step in this direction and aim to collaborate with other departments at KTH. By similar means, we intend to work with our international contact networks and also with other national universities and colleges. Any response on how to coordinate such efforts effectively will be much appreciated.

4. Strategies and organization

5. Interaction between research and teaching

6. Impact and engagement in society

Research has increased knowledge on questions of equality, diversity, and inclusion in planning and architecture and in architectural education. Through internal and international workshops, seminars, symposia, conferences, both on a university level and public, it has contributed to building strong global networks. It has also produced new approaches for critical spatial practices.

The research has increased the knowledge and understanding of how analysis can be productively used in urban design and planning, and how it needs to be critically assessed and developed. It has also produced methods, tools, and approaches that are in use in both public and private planning offices, and increased the understanding of the complex and contradictory challenges of sustainability, social process and Structure, and urban form. This makes for a more nuanced approach to urban development that is better equipped to handle the multifaced challenges of sustainable urban development that can incorporate not only 'places for all' and idealized goals, but the tangled and messy reality of social structures and practices. It has also challenged common ideals and 'models' of sustainable urbanity and developed on shortcomings, weaknesses, and potentials of such challenges.

The research has had an impact on architecture/urban design/planning when it comes to social sustainability. Especially phenomena such as social segregation, unequal living conditions, and urban

life. Moreover, the research is questioning urban models, how things are labeled within the planning and urban design, and has contributed to urban analysis with architecture/urban design in focus. The research is highlighting analytical and generative theories and methods as an alternative to normative theories and approaches

A model for process governance and control where component parts (organization, cooperation, and participation) aims to develop urban development-related innovation and work processes enabling new approaches and solutions for societal challenges.

Department of Civil & Architectural Engineering

1. Overall analysis and conclusion; Strength and development areas

The Department of Civil & Architectural Engineering consists of seven divisions that have individual strengths and weaknesses. At the Department level, we have identified the following major strengths and weaknesses:

Strength

- Wide scientific scope in civil & architectural engineering
- Strong and intensive cooperation with high-ranked international universities
- Several ongoing EU projects
- Strong links to industry and society including public authorities
- Developed cooperation with Chalmers, LTH, and LTU through the network Swedish Universities of the Built Environment

Weakness

- Too small faculty in relation to the amount of teaching
- Too few female faculty positions
- In some sub-areas, the number of new Ph.D. students is too small
- Laboratory facilities far from, e.g., structural engineering laboratories at well-reputed international universities
- Too few cross-disciplinary collaborations

The vast majority of the Department's research projects are devoted to applied sciences. These projects are often co-sponsored from governmental sources and the industry. Most Ph.D. projects have reference groups containing experts from the industry and society. This means that important and innovative research results could be implemented even before publishing the Ph.D. thesis.

Other important tools in the impact work are scientific and popular scientific papers, oral presentations at national and international conferences, work in pre-standardization and standardization committees, debate articles, and carefully selected sideline jobs.

The Department has four divisions devoted to infrastructure: Concrete Structures, Soil & Rock Mechanics, Structural Engineering & Bridges (including Highway Engineering Group), and Transport Planning. All of them contribute substantially to the development of the infrastructure for transport and energy production.

As stated elsewhere in the report, almost all research projects at the Department are devoted to sustainability, primarily environmental and economic sustainability.

2. Research profile

The Department. of Civil & Architectural Engineering (Byggvetenskap) has its origin in one of the two oldest education programs at KTH, i.e., civil engineering (väg- och vattenbyggnad). Currently, it is the largest Department within the School of Architecture and Built Environment and covers almost all technical subjects within the very broad area that the School covers. The only exceptions are hydrology and technical geology. The Department covers building materials, building technology, building services, energy systems, climate technology, concrete structures, structural engineering, bridges, soil mechanics, rock mechanics, highway engineering, and transport planning.

The Department is organized into seven divisions and two research centers. The faculty consists of 32 teachers, 20 researchers, ten administrators, and technicians, about 80 Ph.D. students (40 industrial ones) totaling about 180 persons, including (many) part-time employees.

The Department 's research field covers technical aspects of the built environment, both in infrastructure and real estate. It is much focused on how this will serve the society and how the resources of society can be managed in a sustainable way. A common denominator for almost all ongoing research projects is sustainability, not least considering climate change. So far, the focus on climate change is and has been devoted towards mitigation, but adaptation to climate change has been recognized as an important area for research in the near future. Digitalization is covered in several research areas and covers, e.g., numerical methods, optimization and analysis, Structural Health Monitoring (SHM), Building Information Modelling (BIM), Big Data, Artificial Intelligence (AI), and machine learning.

Below, a list of exciting ongoing projects is presented.

- Condition assessment of concrete dams in cold climate including ice loads
- Construction and foundations of high-speed railway embankments
- Design of timber-based hybrids to enhance the properties of wood in load-carrying structures
- Development of a railway traffic timetable for a given set of departures that minimizes the weighted sum of scheduled travel time and expected delay
- Development of digital twins for critical infrastructures
- Digital twins within hospitals focusing on ventilation systems
- Low-temperature heating of buildings – a part of the EU Geofit project

- Railway bridge dynamics focusing on advanced modeling for future high-speed tracks
- Sustainable and stepwise renovation of apartment buildings
- Test methods for evaluating viscoelastic properties of bitumen-based composites
- User-adapted, smart and sustainable building performance management

The Department is running a large number of research projects. The following projects are examples of projects that have been identified as especially interested in describing the advancement of state of the art:

- A novel risk and reliability-based framework describing the design process for construction in soil and rock
- Damage detection in bridges based on sensor data and machine learning
- Energy-effective logistics and infrastructure systems assessment for cargo ports
- Increased knowledge of modified wood.
- Numerical simulation of hospital ventilation.
- Numerical tools for optimizing the performance of stone-based road materials at large deformations
- Optimization, capacity analysis, and control systems for public transport, freight transport, rail, and road traffic
- Relining of waste-water pipes
- Structural behavior of shotcrete in hard rock tunneling

During the last five years, 48 Ph.D. students have received their Ph.D., and 50 have taken the degree licentiate. The somewhat higher examination volumes during 2015 and 2016 are due to the simultaneous supervision of a number of Ph.D. students by one single professor.

At the Department, we have not been able to make any quality assurance of the data. We do not know if the figures for the various years reflect the publication activities of the employees 2019 or if every single year's figures reflect the activities of the employees that specific year. The number of divisions and thus, employees have varied substantially during these years. Consequently, any conclusions are difficult to draw.

The publication peaks during 2015 and 2016 might be due to the high number of Ph.D. student exams the very same years. There ought to be a phase displacement between publication and citation. The high citation numbers in 2015 might be explained by important publication activities before 2012.

Examples of excellent publications during recent years:

- Balieu R & Kringos N (2015): "A new thermodynamical framework for finite strain multiplicative elastoplasticity coupled to anisotropic damage". Int. Journal of Plasticity, Vol. 70, pp. 126-150 (ISSN 0749-6419, E-ISSN 1879-2154).
- Gasch T, Malm R & Ansell A (2016): "A coupled hygro-thermo-mechanical model for concrete subjected to variable environmental conditions", International Journal of Solids and Structures 91, 143-156.
- Högdahl J, Bohlin M & Fröidh O (2019): "A combined simulation-optimization approach for minimizing travel time and delays in railway timetables". Transportation Research Part B 126, 192-212.
- Laine K, Segerholm K, Wålinder M, Rautkari L & Hughes M (2016): "Wood densification and thermal modification: hardness, set-recovery and micromorphology". Wood Science and Technology 50, 883–894.
- Sadrizadeh S, Tammelin A, Ekolind P & Holmberg S (2014): "Influence of staff number and internal constellation on surgical site infection in an operating room". Particuology 13(1), pp. 42-51.
- Silfwerbrand J (2017):" Bonded Concrete Overlays – Over 30 years of Swedish research and experience". Concrete International, Vol. 39, No. 5, pp. 31-36. (Wason Medal for Most Meritorious Paper in ACI journals during 2017.)
- Svedholm C, Zangeneh A, Pacoste C, François S, Karoumi R (2016): "Vibration of damped uniform beams with general end conditions under moving loads," Engineering structures, vol. 126, s. 40-52.
- Wersäll C, Nordfelt I & Larsson S (2017): "Soil compaction by vibratory roller with variable frequency", Géotechnique, Vol. 67, No. 3, pp. 272-278.

Strong and intensive cooperation with high-ranked international universities, e.g., UPC Barcelona Tech, HTW Berlin, MIT (Cambridge), TU Delft, Univ. of Hawaii, Aalto (Helsinki), Univ. of Illinois, KU Leuven, UCLA (Los Angeles), Univ. of Melbourne, Univ. of Sapporo, Univ. of New South Wales (Sydney), INSA de Rennes, NTNU (Trondheim) & Politechnica Timisoara.

Developed cooperation with Chalmers (Göteborg), LTH (Lund), and LTU (Luleå) through the network Swedish Universities of the Built Environment (Sveriges Bygguniversitet), not least within a Graduate School with joint Ph.D. courses. Developed cooperation with Research Institutes of Sweden (RISE) with, e.g., several industrial Ph.D. students.

Centre for Indoor Climate and Energy Performance in Buildings (Centrum för inneklimat &energiprestanda i byggnader, CIEB). Innovation platform for long-lasting, multi-disciplinary cooperation for user adjusted, sustainable maintenance of buildings focusing on indoor climate and energy performance – a cooperation between KTH, Chalmers, LTH, Jönköping Univ., KI (Karolinska Institutet) and 30+ leading actors in operation & maintenance of buildings.

Centre for Traffic Research (CTR). Collaboration with LiU (Linköping) and VTI (Swedish National Road & Transportation Research Institute) on modeling and analysis of traffic processes.

Individuals are active in international organizations such as American Concrete Institute (ACI), Conseil International du Bâtiment (CIB), Fédération Internationale du béton (fib), International Association for Bridge and Structural Engineering (IABSE), and Federation of European Heating, Ventilation & Air-Conditioning Associations (REHVA).

The latest RAE at KTH was carried out in 2012. Among the general recommendations given by the 2012 panel, the following ones with importance for the Department may be cited:

In addition, the area of sustainability, as a holistic approach, needs to be lifted to a higher level in order to get a shared understanding of the concept and formulate its aspirations. Another suggestion was to recruit more international faculty in order to maintain intellectual diversity. Gender balance is an area where a continued effort is needed. The panels mentioned the importance of active work in achieving an equal gender balance. To make basic research more visible, it was recommended that KTH researchers publish more often with external partners. KTH could also consider reappraising its processes for identifying research output worthy of commercialization and that patenting and innovation activities ought to be strengthened through education and networking with industry.

During the latest eight years, the focus of the research has been towards sustainability in almost all new research projects. To apply successfully for research money without focusing on sustainability is hardly possible. Contrary, we are working with eight of the 17 SDG.

We have increased publication activities with external partners during recent years (Figure 3). Furthermore, our research can be characterized as applied research, and many of our research projects lead to innovations that are implemented in the industry or society (cf. Section 6d). Patents are, however, not frequent in the construction sector. Absence of patenting traditions, difficulties in keeping innovations secrets on open construction sites, and the importance of a large governmental client (Swedish Transport Administration, Trafikverket) that wants every contractor to use the very same innovations are three explanations.

For the Department of Civil & Architectural Engineering (Unit of Assessment, UoA), the following recommendations were stated:

For the successful future of the UoA, priorities should include close research interactions among the members of the UoA; and collaborations with the national and international construction industry, building owners and authorities, and top researchers in sustainability, reliability, infrastructure maintenance and management, life cycle cost of civil infrastructure, and optimization. The panel recommends the establishment of a research center for green, smart, economical buildings and

transportation infrastructure to establish necessary collaborations and provide access to laboratory facilities. Other recommended facility enhancements include updating and enlarging the material and structural laboratory and establishing at least one experimental facility to demonstrate innovative materials and building technologies under real-world conditions.

The Department has a long tradition of national and international collaborations with both industry and society, so the first recommendation is somewhat difficult to interpret. We have ongoing research projects in all areas mentioned in the list.

A center for the transport infrastructure – Road2Science – was established in 2012. It has been very successful with research application activities. Road2Science has changed its agenda recently and is now working, e.g., with a Graduate School within its field together with Nordic universities. Besides, there is a Centre for Sustainable Built Environment (Centrum för hållbart samhällsbyggande, CHS) at the ABE School level. It treats issues other areas mentioned in the recommendation.

Due to economic restrictions, lack of funding, and decreasing industrial demands, the Department has been able to update neither its materials & structural laboratory (with the exception of the asphalt lab) nor its climate chamber. However, the existing one (despite decreased area) has been recognized as a KTH research infrastructure (laboratory). At the beginning of 2020, the Department has strengthened the laboratory staff. A few years ago, the Div. of Structural Engineering & Bridges bought equipment for making dynamic tests on bridges. Laboratory works are not limited to a certain building.

3. Viability

The Department's total revenue is 167 Million SEK (2019). The research is totaling 96 MSEK. It consists of faculty funding (34 MSEK), external governmental funding (56 MSEK), and external commission works (6 MSEK).

Research matters are discussed at four different types of meetings, if not more: (i) research project meetings, (ii) division meeting, (iii) meetings in the Counsel of Professors, and (iv) Department workshops. Most Ph.D. projects and several other research projects have regular reference group meetings every semester. The reference group consists of the Ph.D. students, the supervisor and the co-supervisors, and representatives from industry and society (e.g., *Trafikverket*). The divisions arrange division meetings, and progress in ongoing research projects is often on the agenda. The Council of Professors meets every second week, focusing on one specific issue, not rarely research and research quality. In August every year, all employees at the Department are invited to a two-day workshop on a hotel venue in greater Stockholm. In the 2018 workshop, publication and citation strategies were

discussed. One year later, research cooperation, the interaction between research & education, and Department aims were discussed.

Currently, the faculty at the Department consists of nine full professors (and in addition one full professor with employment at VTI), eight associate professors, two assistant professors, and 13 lecturers. Two professors, one associate professor, and four lecturers will have reached the age of 65 (traditional retirement age in Sweden) in 2024.

Among the 32 people, only six are women (19%), which is much less than the share of female students on the Master level (approx.. 30%). However, during the latest five years (2016-20), the amounts are more even. Six women and eight men have been either promoted or recruited to faculty positions.

Any recruitment strategy has to follow the KTH regulations. That means that the degrees of freedom are limited, especially concerning faculty positions. Before being able to recruit full, associate, and assistant professors, we need to show that we have a sufficient amount of faculty funding. Duties in education and external funding are not sufficient. Since the entire ABE School lacks faculty funding, the reader of this document may understand the difficulty in this very important task. Not even in case of retirement, there is a guarantee that we will have funding for recruiting a successor. By dividing the faculty funding that the Department has, we have been able to recruit two associates and three assistant professors since 2016. Some of these have later on received additional faculty funding from the School. The strategy for prioritizing subjects and divisions for these new positions has mainly been based on a combination of needs and economic possibilities.

The recruitment of lecturers is easier since the Department has a large volume of education duties, and the lecturers almost exclusively teach. Here, we have had a lot of retirements and dropouts in the industry. The recruitments can be regarded as replacements.

There is another possibility to recruit, and that is to positions as researchers. These positions do not need any faculty funding and are financed by external research money. The Department has nearly 20 researchers, of which many also work part-time at various companies. Without the work done by these people, the Department would not be able to carry out its many research projects. Researchers are also involved in the supervision of Ph.D. students. Some of these have received the Docent title enabling them to act not only as co-supervisors but also as primary supervisors.

However, the Department has a long-term goal to enlarge its faculty. Almost all divisions are in need of new faculty positions to share the research and education duties. As shown in Figure 4, most of the professors are born before 1970. There will be a severe shortage of full professors in the 2030s if the Department does not succeed in hiring new faculty. The coming recruitment need can simultaneously be turned in something positive; it gives the Department the possibility to make the gender balance more equal.

Here, it can be added that the Department 's center Road2Science organizes the Gender Gap conference in May 2020, in collaboration with many SIPs, Centers, Vinnova, and Formas (see http://www.road2science.se/gendergap/). The aim of the conference is to raise the awareness of decision-makers about the urgency to deal with gender data bias within the transport infrastructure.

The Department is located in two neighboring buildings at the main KTH Campus, Brinellvägen 23 and Teknikringen 78. The Department rents a sufficient number of office rooms, seminar rooms, coffee rooms, etc. At Brinellvägen 23, the Department rents laboratory halls. The laboratories contain the following parts and equipment:

- Minor laboratory for strength testing (using a minor MTS machine) of material samples and small test specimens
- Laboratory for production, testing, and analysis of material samples in asphalt and concrete
- Tomography for analyzing materials with possibilities to temperature control and simultaneous loading of a test specimen
- Inverse gas chromatography (IGC) equipment for surface energy analysis of particulate and fiber materials
- Two major MTS machines located at Drottning Kristinas väg 26 and co-used of the Department and the Research Institutes of Sweden (RISE)
- Equipment for dynamic loading of bridges in-situ and measuring equipment for assessment of bridges

4. Strategies and organization

The research has double aims: (i) to enable education on a high level and (ii) produce research results implementable in the industry and the society. The education should attract good students and give them the training to become employable, meeting both current and future industrial and societal needs. The research should maintain its depth and width spanning over the entire area of civil and architectural engineering. The Department should be the first choice for problem owners like the Swedish Transport Administration (*Trafikverket*) and an attractive partner for European universities and research institutes searching EU funding.

KTH's current development plan contains the following headings:

1. A leading KTH
2. An integrated KTH
3. A visible KTH
4. An open KTH

5. An increasingly digitalized KTH
6. A more sustainable KTH
7. A more international KTH
8. An equal-opportunities KTH

The most important message could be summarized in the following quote: "A leading KTH /…/ is characterized by digitalization, sustainable development, internationalization, and equal opportunities." In our leadership and organization, we try to provide equal opportunities for everyone independent of gender, background, etc. However, KTH seems to evaluate equal opportunities through equal results in the case of gender.

The Department is led by its Department Head and Deputy Department Head. A Division Head leads each division. All these leaders are composing the Leading Group (LG) also containing the Administrative Head, the Director of Studies and the Laboratory Manager. LG meets six times annually and deals mainly with economy and HR matters. Besides, there is a Counsel of Professors (CP). It meets every second week and discusses a specific issue. It prepares decisions to be taken by either the Department Head or the LG. Besides, there is a Teaching Staff Meeting (inviting all teachers at the Department), chaired by the Director of Studies, discussing education matters and a Research Education Board, chaired by the Program Director, discussing research education matters.

Almost all research projects rely on external funding, which is won in national (most frequent) or international (EU projects) competitions. This is a quality recognition of both the previous research (cited in the application) and the outline of the upcoming research project.

Ph.D. students conduct the majority of the research. Almost all Ph.D. students are writing compilation dissertations. The dissertation is usually containing four or five scientific papers, published or submitted to international scientific journals with referee system. In some cases, papers from international conferences with referee systems can be included. Furthermore, all Ph.D. theses are reviewed prior to publishing. Usually, this review is carried out by a colleague at a neighboring division. This cooperation across the division borders contributes to maintaining a high and even scientific level within the Department.

5. Interaction between research and teaching

Most of the Department's teachers are active in both teaching and research. The BSc program Byggteknik & Design (Building Technology & Design) is an exception where a considerable part of the

teaching is done by lecturers (who usually do not research). In the MSc program, the number of lecturers is small. Either professors or associated professors and researchers with a Docent title lead the teaching and supervision of Ph.D. students.

The connection between research and teaching increases in more advanced courses and in the MSc thesis works. Most of the Department's research is carried out in Ph.D. student projects. That means that the interaction between research and teaching at the Ph.D. level is obvious.

6. Impact and engagement in society

The Department's research is almost unexceptionally applied research, which is carried out with external funding. That means that the research funding is obtained in competition with other applicants. Relevance to society is usually one of the criteria that the research councils are considering when selecting research projects. As shown in Section 3a, the largest funding agency is the Swedish Transport Administration (*Trafikverket*). Here, it is impossible to receive research funding for research projects without high relevance for the Administration that has a rigorous process in evaluating the relevance of potential research projects.

The main channel for dissemination of research results is through the examination of MSc and Ph.D. students. Another important channel is through adjunct professors (the Department has 10), researchers with employment at both KTH and a company, and industrial Ph.D. students (approximately 40). Some faculty members combine KTH employment with carefully selected sideline jobs. Both faculty and Ph.D. students are active at national and international conferences and write a decent number of popular science papers annually. Some employers participate in international committee work, pre-standardization, and standardization; these or others write debate articles, participate in media, contribute to the development of handbooks and develop a response to governmental investigations and proposals.

Another possibility to disseminate research results is networking. The Department leads two KTH Centers – Road to Science (R2S) and Centre for Traffic Research (CTR) – and is active in a third one – Centre for Construction Efficiency (CBE).

Sustainability and the United Nations' Sustainable Development Goals (SDG):

Goal 4: We are running a pilot project on how we can connect education levels (from primary [two primary schools and a secondary school] to higher education [KTH]), industrial facilities, and communal sustainability challenges to each other.

Goal 5: Led by the Highway Engineering Group, we try to (i) increase the visibility of a variety of female role models to our students, (ii) increase the number of female students and female academic staff and (iii) raise the awareness, as well as actively develop activities to diminish the risk of the gender data gap in the transport infrastructure sector.

Goal 7: Research on water power stations and dams.

Goal 7.2: Methods for maintaining Swedish water power stations and dams.

Goal 7.4: Risk-based design methods for hydrogen gas storage in rock shelters (in cooperation with the steel industry)

Goal 8.5: Methods minimizing risks for a safe working environment in construction in rock and soil.

Goals 9, 11-13: An increased proportion of renewable biobased building materials in the building sector.

Goal 9: Enhance (through, e.g., digitalization) a scientific research that will lead to an upgrade of the technological capabilities of the transport infrastructure sector as well as encourage innovation

Goal 9.1: Minimizing material and natural resources, promoting sustainability in infrastructure construction.

Goal 9.4: Updating and prolonging the service life of civil engineering structures, e.g., dams and tunnels.

Goal 11.1: Safe and affordable housing

Goal 11.1: Sustainable stepwise renovation.

Goal 11.2: Development of cost-efficient construction in rock and soil facilitating the construction of urban public transports, in turn, improving availability. Shifting mobility from private cars to public transport.

Goal 11.6: Reduce the environmental impact of cities.

Goal 11.6: CIEB.

Goal 13: Reducing climate footprint from concrete structures through reducing cement content, utilizing industrial by-products, optimizing cross-sections, LCCA and LCA, improving maintenance and repair.

Goal 17: International research cooperations.

Impact cases

Hea-ding	Problem	Research method	Main result	Implementation

Bus Stops	Growing Stockholm leads to increased demand for public transport services & facilities, incl. bus terminals. Difficulties were providing the needed space for bus stops & bus terminals.	Literature review, field studies & modeling of the capacity of different types of bus stops & terminals. A model of capacity based on bus dwell time described by HCM2000 was further developed.	A novel method for the calculation of capacity in bus stops & terminals. Results from performed trials show that the correction factor (developed in the project) is reduced at higher dwell time.	The new formula is used by the Traffic Administration in Stockholm to develop a new Manual for capacity calculation for bus stops & terminals. It has already been used for 40 terminal surveys.
Cleaning Swimming Pools	Chlorination causes unhealthy gases, which affect those who bathe & work in the bathhouse. The swimming pool & the building corrode. The bathhouse water purification & ventilation systems are damaged.	Review & evaluation of alternative water treatment methods developed by Teknikmarknad AB. Analysis of data from Stockholm Environmental Management.	Chlorination alternatives, with blue light & photo catalysis, reduce the need for chlorination to less than half. This provides a better working environment & prolonged service life for the swimming pool.	The method is tested in a teaching pool. It will now be implemented in a regular pool at Västertorp-Stockholm.
Controlling Vibratory Rollers	Compaction in infrastructure projects comes with high costs & environmental impact.	Compaction with variable frequency in laboratory tests & full-scale tests.	Compaction at the resonant frequency increases efficiency & lowers environmental impact considerably.	Automatic frequency optimization has been implemented for vibratory rollers & is available on the market from 2019.

InfraSweden 2030	Innovation capacity of the infrastructure sector is too low, due to GAPS: (1) Lack of a system perspective. (2) Lack of reducing risk averseness that countervails possible creativity. (3) Too small attractiveness of the infrastructure sector. (4) Frozen market dynamics preventing new collaborations	From discussions & structured interviews with industry partners within the KTH Road2Science Centre, a structured agenda to counteract the sector's biggest causes of a too slow rate of innovation was developed.	Development & successful submission of (1) A national Green Infrastructure Material Innovation ('GIMI') agenda, funded by Vinnova (2013-2015). (2) Development of the Strategic Innov. Progr. InfraSweden2030, funded by Vinnova, Formas, Energi-myndigheten & industry (2015-2018-2021)	2015: Start of the long-term InfraSweden2030 strategic innovation program (140 MSek for first 3 yrs.), in 2018 extended by another 3 years & up for long-term evaluation 2021. The SIP gives the possibility of a structured program that not only provides funding to the field but also systematically tries to address the most relevant long- & short-term aims related to the defined GAPS.

Öland Bridge	The 6 km long Öland Bridge connects the Swedish mainland & the island of Öland. Code-based assessment of the bridge showed a limited capacity to carry current heavy traffic loads.	(1) A sensor-based monitoring campaign monitored traffic loads & vehicle positions on the bridge. (2) Collected sensor data were used to create critical traffic convoys that are used in simulations. (3) A probabilistic assessment method was used to better check the actual bearing capacity.	The probabilistic assessment results showed a large reserve in bearing capacity, which means that we can increase the allowable axle loads on the bridge without jeopardizing the bridge safety & functionality.	Based on our investigation, Trafikverket issued a decision to allow a higher axel load on the bridge.
Resilient Energy Systems for Remote Environments	Securing the sustainable & robust energy supply for the Islands of Maui, Molokai & Lanai (Hawaii) as part of the sustainable development strategy for the State of Hawaii, as well as to safeguard emergency energy & water supply in the case of natural disasters	Energy system modeling at the community level.	Resilience Hubs.	Securing the sustain-able & robust energy supply for the Islands of Maui, Molokai & Lanai (Hawaii) as part of the sustainable development strategy for the State of Hawaii, as well as to safeguard emergency energy & water supply in the case of natural disasters.

Thermal Cracks in Concrete Dams	Significant cracks occurred in several concrete dams due to seasonal temperature variations.	It has developed theoretical & numerical methods that can predict cracking & simulate the response of the dam.	With the developed method, it was possible to predict & explain the root cause of these cracks & to determine their influence on dam safety. The new design solution was suggested to prevent further cracking.	The developed method has been implemented in research & by the industry, both nationally & internationally. Many dams rebuilt based on the suggested design solution.

As shown above, the Department has already rather extensive impact activities. A further increase should rather focus on increasing its intensity than its extent. This can be done by a more careful selection of dissemination channels. The Department has hired a person responsible for the information, and she is continuously working with improving the Department web www.byv.kth.se and other modern tools.

Department of Philosophy and History

1. Overall analysis and conclusion; Strength and development areas

Strengths

- Strong, multidisciplinary, well-integrated, and collegial research environment, highly diverse, gender-equal, international, visible, and attractive to international colleagues and guests. Enormous growth since RAE2012.
- Research of high societal relevance and impact, capturing important themes of social and environmental sustainability, e.g., climate, resources, energy, bioscience. Collaborative ties to parts of ABE and KTH (e.g. KTH Water Center, KTH Sustainability, KTH Energy Platform, StandUp Strategic Energy Research, School of Architecture, Dept of Learning). Successful PhD training.
- Excellence in acquiring external funding. Increase of external grants since RAE2012, incl. several large EU-funded projects. Considerable growth in income and the number of employees.
- Excellent publication record, with consistent growth in volume and improvement of quality since RAE2012
- Strong engagement in societal debate and providing policy advice. Serving multiple audiences: international and Swedish publications and collaborative networks, despite the majority of staff not fluent in Swedish.

Weaknesses

- Uncertainty of funding situation due to low core funding, low returns on education, and large dependence on external funds. Exceptionally high university over-head costs require co-funding, infringing on core funds. Lack of funds to replenish and develop faculty in step with the growth of research operations weakens sustain-ability. External funding of doctoral student positions limits the number of doctoral students that can be admitted.
- Unbalanced size of divisions, increasing the funding instabilities of our operations; both divisions struggle with sustaining their level of research activities
- A Low degree of collaboration between the two divisions aggravates the imbalance and risks isolation. Limited collaboration within the school and the institution.
- Uncertainty of position of the humanities within KTH. Continued low recognition despite some improvement.
- Bibliometric performance assessments miss to cover humanities' publication traditions and formats (books, book chapters, works in Swedish and other non-English languages) and use citation time

windows that are too short of acknowledging humanities citation practices and WoS as the source, which has low coverage in humanities.

Development Areas:

- Humanities at KTH

Develop the presence and significance of the humanities at KTH and ABE, according to KTH Development Plan 2018-2023. Work towards the recognition of the humanities' importance in the education and future professional engagement of engineers in society. A Masters' program (or two) would be an obvious step.

- Cooperation

Cooperate in and beyond the department, to be sustainable at ABE and KTH. Pool research interests and competencies and reach out to new partners in and outside of academia.

- Beyond Philosophy and History

Continue working towards inter- and transdisciplinarity to contribute to sustainable transitions. Continue to reflect on the affordable scope of multidisciplinarity in a department limited by funding uncertainties and risk diluting core competences.

- Funding

Develop a more stable funding situation. Aim to acquire more basic funding from KTH, as well as long term platform grants and donations from private funders.

- Faculty Development

Build a solid faculty that can meet generational shifts and stabilize core operations while hosting temporary researchers and research projects. Reflect on and, when indicated, adjust the balance between the number of faculty members based on limited core-funding and a growing number of researchers relying on soft money.

Contributions of the department on impact, infrastructure, and sustainable development:

- Impact: high societal impact through informing and engaging civil society, participating in societal debate, giving policy advice, and affecting policy changes. Influence on research policy; university governance; climate, media, and energy policy.
- Infrastructure: The Environmental Humanities Laboratory (EHL) and the Post-amenities Hub built up highly visible collective research networks with outreach and impact beyond academia, utilizing untraditional media for scholarly publishing.

- Sustainability: high-profile work on environmental philosophy, history, and humanities aiming at analysis, achievement, and improvement of SDGs; research and initiatives on energy transitions, climate change, environmental governance, behavioral change, emission goals, engineering solutions, and engineering ethics.

2. Research profile

The Department of Philosophy and History is composed of the Division of Philosophy and the Division of History of Science, Technology, and Environment. The Department of Philosophy and History is one of six departments at ABE School of Architecture and the Built Environment, one of five schools at KTH. The department is also the place at KTH and ABE, where research in the humanities is most concentrated and distinct.

At the end of 2019, the Department employed ca. 75 people of which ca. 1/3 were employed at Philosophy, 2/3 at History. The Department is led by the Head of Department/Prefekt (currently from History, with the Vice-Head of Department from Philosophy) who represents the department in ABE's steering council. The two divisions maintain largely separate operations led by the Heads of Division. The divisions' economies are also separate. The shared economy part concerns the overhead budget, which covers common departmental functions and infrastructures. Partly joint departmental functions are leadership, administration, directing undergraduate studies, and directing graduate studies. The latter function concerns running the joint departmental Ph.D. program "Studies in the Humanities and Social Sciences of Technology, Science and the Environment".

Research at the *Division of Philosophy* covers a wide variety of topics, research questions, and themes, but its main overall focus is the philosophical aspects of technology and its role in society. Research areas include

- Philosophy of technology.
- Philosophy of risk.
- Ethics of technology, particularly social and environmental aspects of the built environment, biotechnology, climate mitigation, artificial intelligence, sustainability
- The ethics, methodology, and epistemology of institutional decision making

The division also has a strong presence in more theoretical areas of philosophy:

- Philosophy of science, particularly in the methodology and epistemology of scientific modeling
- Logic and formal semantics
- Formal epistemology.
- Decision theory and the philosophy of economics

This mixture of applied and theoretical themes is the division's hallmark. Although a fairly small philosophy division, the competencies are broad. Apart from the core competences of philosophy, faculty or research staff have degrees or long working experience in law, civil engineering, toxicology, computer science, environmental science, risk analysis, and cognitive science.

A substantial portion of the research at the division is multidisciplinary and is done in collaboration with researchers from other areas, as well as decision-makers in the EU, the Swedish government, and Swedish municipalities. Ongoing projects collaborate with researchers specialized in traffic safety, genetics, molecular biology, climatology, geology, clinical medicine, computer science, and environmental economics, as well as with decision-makers at The Swedish Transport Administration and in several municipalities. For instance, the project SEA-RIMS (headed by Per Wikman-Svahn), which addresses ethical aspects of mitigating sea-level rising due to climate change, is performed in collaboration with the Swedish Geotechnical Institute, the Council of the Baltic Sea-states, two regional governmental bodies, and six municipalities. Another example is Ethics in Biodiversity Offsetting (headed by Mikael Karlsson) which addresses ethical and legal aspects of biodiversity offsetting, which involves collaboration with environmental lawyers, NGOs as well as decision-makers at a national and local level.

Philosophy is traditionally a male-dominated subject that comes with a myth of the philosopher as the "male-genius", often fostering a rather aggressive culture. At the division, we have actively tried to counterbalance this image in recruitment and in fostering a more inclusive culture. We suspect that the non-traditional focus on applying philosophy to problems that are of direct relevance to society makes the division more relevant for female researchers. Of the seven researchers currently employed, three are female. Among the seven Ph.D. students, three are female. At the level of faculty, there is room for improvement. Among the four faculty of four, one is female. The division has two professors, both male.

Research at the *Division of History of Science, Technology, and Environment* addresses scientific, technological and environmental developments in their social and cultural contexts and impacts in the modern period, with a focus on the 20th and 21st centuries: Sustainability studies/Anthropocene history:

- Environmental humanities (since 2012) and Posthumanities (since 2018)
- History of natural resources, resource extraction & management
- History of infrastructures & large technical systems, including media
- Cultural/industrial heritage studies, industrial archaeology
- Arctic and Polar history
- Environment, energy, climate, water, waste – their historical sciences, technologies, politics and governance
- Environment and migration – their cultural and social histories

- Urban ecology, urban studies
- (Environmental) media technology and communication
- Research policy, higher education studies & innovation studies

With a unique combination of strong research cores arranged around broad contemporary questions of human-environment relationships, the division has furthered a humanities research agenda for sustainable development. Research approaches are integrative, informed by STS, political ecology, cultural theory, and media studies. Research is cross-disciplinary with a transnational or global historical perspective.

Since 2012, the division experienced enormous growth in external funding and in the numbers of co-workers, beginning with the founding of the Environmental Humanities Laboratory (EHL) in 2011, enabled by a private donation. The EHL helped launch our participation in the new international field of the environmental humanities. We have contributed actively to shape this field while maintaining our historical focus. Our participation in the Marie Curie ITN "Environmental Humanities for a Concerned Europe" (ENHANCE) (2015-2019), together with Leeds University, the Rachel Carson Centre in Munich and the Deutsches Museum in Munich, brought four Ph.D. candidates with backgrounds other than history (environmental humanities anthropology, sustainability studies) to the department's Ph.D. program. Our multidisciplinarity has benefitted us also in the field of polar research, which combines the history of technology, environmental history, social and cultural history, and industrial heritage studies. The division became the hosting partner of a Nordic Centre of Excellence in Arctic research, funded by Nordforsk (Oslo) and in collaboration with 14 other partners in eight circumpolar countries (2016). In 2015, the program Making Universities Matter (MUM), funded by Vinnova and in close collaboration with Lund University and Technopolis Group Ltd (UK), invigorated research policy as a core area of investigation at the division, with the appointment of a guest professorship in Research Policy. Our successful broadening of environmental issues is demonstrated by three ERC grants on environmental, energy, and polar research that researchers at the division received between 2016 and 2018.

Our research focuses on environmental sustainability, and justice attracts international scholars, both women and men. At the turn to 2020, the division counts close to 50 co-workers and pursuing a total of 50 research projects (of various sizes) and with a turnover of 55 MSEK (2019), of which only some 10 percent is KTH core research funding. All faculty members and nearly all of our researchers lead research projects, some individuals but most involve several colleagues across career levels, including postdocs and, if funding allows, Ph.D. students. The division has become increasingly more multinational and multilingual. Roughly 50 % is born outside of Sweden, and roughly 40% are women. We attract a growing number of guests and visiting scholars from all over the world.

The *Department of Philosophy and History* at KTH differs from a traditional humanities department. At an institute of technology, the divisions specialize in scope, focus, and expertise. We comment on modern science, technology and their societies, built environments and socio-technical infrastructures, targeting present-day societal problems. Our work is inter- and transdisciplinary and we believe it is also transformative: it transforms others, the humanities and ourselves more broadly. Research is situated at the edge of our traditional disciplines, which we advance by developing new research fields and methodologies, e.g., the environmental humanities, posthumanities, Anthropocene history, and the ethics of traffic safety or radiation protection.

Research-wise, the *Division of Philosophy* is heavily focused on publishing research in international journals that employ the system of peer-review, and so to contribute to the international state of the art within the research fields of the department. For instance, our PhD-students do not write monographs but are instead expected to produce a dissertation consisting of 4-6 articles that are published, or at least are publishable in such journals. This has been successful; roughly around 75% of the articles included in our PhD-dissertations have been published by the time the PhD-student is finished. We strive to publish our research both in traditional philosophical journals (e.g., *Ethical Theory and Moral Practice*, *Philosophical Studies*, *Analysis*) but also – importantly – in non-philosophical journals to reach researchers outside of philosophy (e.g., *Journal of Risk Research, Energy Policy, Artificial Intelligence*). In all more than 100 publications between 2015-2019, including 20 by Ph.D. students. In addition, in this period, researchers at the division have produced four edited books and two monographs.

The *Division of History* has developed integrated humanities research in defining and transformative ways. Through widening our scope, diversifying, and increasingly claiming our stakes in education, society, and politics, we have worked towards affecting and changing societies in a broad sense. Since RAE2012, we have witnessed profound internationalization and successful grant acquisition, paralleled by an increasingly global scope of our research and collaborations. We have enhanced the diversity of our research while maintaining our core focus in history, which has led to novel and often quite unique combinations of approaches and research outputs, e.g. in integrated polar research that draws on political science and material cultural studies; in the climate humanities that range from climate monitoring to climate migration studies; or in the visual environmental humanities including film, art, and activism. Our publication record has grown stronger and more diverse while retaining strength in Swedish publications. We have increased our engagement and influence in our wider international academic communities, our closest academic networks, e.g., Tensions of Europe, and societies, e.g., Society for the History of Technology (SHOT) and European Society for Environmental History (ESEH). Since 2012, the division has offered a venue of exchange by organizing and hosting several large conferences (7th Tensions of Europe meeting 2015; political ecology conference “Undisciplined Environments” 2016; environmental humanities conference “Streams” in planning for 2020).

The department's publication profile is only partly discernible in the bibliometric data for RAE2020 (a bias flagged in the intro page to the Excel file). It treats philosophy and history as one, although they have different publication traditions and records of accomplishment. Moreover, it does not pay attention to the publication outlets and formats and the circulation and citation of published material in the humanities. Implications: A) Only a limited portion of our publications, those listed in WoS, are included in our citation count. On this score, we are an outlying unit of KTH (and ABE). B) All data are absolute numbers, which obscures the relationship between research output and core funding. We estimate that our peer-reviewed research output is comparatively high in relation to core funding. High is also our external research income, which enables us to, nonetheless, to maintain an intense publishing pattern. C) Our publishing style is a mix of co-authorship and individual authorship. The latter is necessary to build a career in the humanities, and we maintain it in multiple ways as part of our quality work. Hence, the indicator of co-authorship as a proxy for 'collaboration' is misleading for our department. Collaborate we do, but mostly in other ways than writing papers with our non-academic partners.

Consequently, we have no good coverage of our citation patterns. Google scholar gives more adequate information than WoS or Scopus data. Compared to Swedish philosophy and history departments, our (admittedly not detailed) impression is that the department fares well in research volume, visibility, and impact from research. We pay attention to patterns and strategies of publishing to enhance circulation and impact. We train Ph.D. students and postdocs to select formats and outlets carefully.

Based on google scholar, the researchers at the division of philosophy (not counting PhD-students) have acquired more than 7000 citations in the period 2015-2020, which is a very high number given the subject and the size of the division. Roughly 5000 of these come from one individual (Sven Ove Hansson), but this still leaves more than 2000 citations for the other researchers.

Since RAE2012, History shifted towards publishing scientific articles in international journals and university press books. This is in line with a general trend in Swedish humanities, although far more pronounced. Outlets include broad-spectrum high-impact journals such as *Science, Nature, Nature Climate Change, Climatic Change, Global Environmental Change*, as well as disciplinary flagship journals such as *Isis, Technology & Culture, History & Technology, Environmental History, Environment and History*, and crosscutting thematic journals, e.g., *Social Studies of Science, Energy Policy, Polar Journal, Minerva*. In the previous decade, the output of peer-reviewed journal articles, books, and book chapters (combined) by Division members grew from

nine in 2010 to 78 in 2019. At the same time, we have maintained a high profile of publishing in Swedish for wider audiences, policy, and public and civic discussion. The most cited division member has 16 000 Google scholar citations since 2015. Other members of the division have high citation rates above 4 000, several between 300 and 2 000.

The department engages in a number of larger, mostly international, projects and programs, often as lead or hosting institution. We organize much of our work in broad multi-year projects, sometimes with considerable 'deep' interdisciplinarity, sometimes with non-academic institutions, and with experimental and outreaching formats for mobilizing public and stakeholder participation and presenting results.

Philosophy: We cooperate, e.g. in the projects: Mistra Biotech: Swedish Agricultural University, Lund University, Umeå University; Stockholm Centre for Health Care Ethics, CHE: Stockholm University, Karolinska Institutet; Modal modeling in Science: University of Vienna, University of Stirling, LSE; Boosts vs. nudges: University of Helsinki, Max Planck Institute for Human Development in Berlin.

History: We practice cooperation on various levels. We have strategic cooperation with crucial players in our field of the environmental humanities, such the Rachel Carson Center in Munich and the Center of Culture History and Environment in Wisconsin; the Max Planck Institute for the History of Science in Berlin which runs the Anthropocene Campus and Curriculum, a worldwide multi-year collaboration supporting engagement in the Anthropocene debates since 2014. Strategic cooperation collocates our research environment on the global map. We have capacity building cooperation where we involve in supporting the development of research environments elsewhere, as, e.g., the Roma Tre University and the Swiss Environmental Humanities Hub, or the project CHEPIS (Center for Higher Education, Policy, and Innovation Studies), a SIDA funded five-year advanced postgraduate training program with seven Ph.D. students (two enrolled at the division) and one postdoc pursued in collaboration with U Eduardo Mondlane, Maputo, Mozambique and U of Western Cape, South Africa. This cooperation has confirmed our role in the international academic arena. Societal engaged cooperation has led us to work closely with non-academic partners, such as grassroots organizations, local authorities, cultural institutions, and governmental institutions, e.g., CLISEL, a Horizon 2020 project involving U Bern, U Lancaster, U Cagliari, and the Association of Local Authorities of Sardinia region. Societal cooperation has a cyclic dimension; it transfers scientific knowledge to societal actors, and it changes the ways in which knowledge is co-produced. Finally, we engage in instrumental cooperation in relation to research projects that require specific knowledge and expertise. This cooperation is limited to projects but may lead to stable collaborations. An example is the division's engagement in the NordPlus-funded project Bringing Research Into Green Humanities Teaching (BRIGHT), a collaborative teaching

initiative involving partners across the Northern and Baltic regions hosted by the Greenhouse at U Stavanger.

Members of the division have conducted research visits as fellows at Institutes for Advanced Study (or similar), often with considerable impact on the research profile and output of our scholars during and after their visits. Among those are IAS Princeton, the Princeton Environmental Institute; Rachel Carson Center, Munich; KRITIS TU Darmstadt; CAS at the Academy of Sciences, Oslo; Peder Wall Center, UBC Vancouver; Netherlands IAS in Wassenaar (now Amsterdam).

In RAE2012 and RAE2008, we were evaluated as a unit combining the Division of History and the Division of Philosophy. Our research unit was ranked excellent/AAA, together with 14 other excellent units at KTH, which resulted in more core funding for both divisions.

The assessment panel's recommendation to "develop a long-term strategy on how to maintain this very high level of performance in the light of the problem of the medium-term succession of several of their key leaders" has posed an ongoing challenge, especially the aim of faculty renewal and long-term faculty stability. Philosophy has not recruited new core faculty since 2012 and lost two faculty members during this time. History recruited two associate professors in environmental history but lost three faculty members, one because of retirement. We plan to recruit three associate professors in the department.
Another recommendation in both RAE2008 and RAE2012 was for KTH to find ways to utilize the expertise of these two divisions in undergraduate and master level teaching. This recommendation has been left unheeded, despite efforts from the department to energize the process. The trend has been a downward one: instead of strengthening our position in KTH's engineering programs, our courses have, on multiple occasions, been sacrificed in the context of the restructuring of programs –also by our own school.

3. Viability

The Department receives its research funding from external sources in Sweden and the EU (as yet little from funders beyond Europe). We have a marked profile towards the most competitive theoretical and high-end ('basic') research funders, notably the Swedish research council (VR), Riksbankens Jubileumsfond, the Swedish Agency for Sustainable Development (FORMAS), the Swedish Foundation for Strategic Environmental Research (MISTRA), and increasingly the European Research Council and other European sources. Broader calls are more common and interdisciplinary competencies in demand. Given our narrow core funding for research and teaching, we have, over the last 15 years exploring a strategy to broaden our expertise in the adjacent humanities (and to some extent social sciences and artistic research) in order to tap into these sources. We have built efforts to shape research teams and

create proposals with a mix of internal and external scholars. We have developed processes for assessing external proposals for collaborations, thereby broadening our base of expertise and competitiveness.

The more successfully our strategy works, the more precarious the relation has become between core funding and competitive grants. The critical factor is the lack of mechanisms with which to acknowledge and support excellent research performance and link it strategically to a conscious effort to build the presence of humanities and social sciences at KTH. Despite our large access to external funds, we experience a lack of freedom to use resources pragmatically, which constrains, in our view unnecessarily, for example, our ability to co-fund Ph.D. students on their 4-year full-time positions.

The department works towards openness and inclusivity by fostering a multiplicity of disciplinary perspectives and identities. We must improve on gender balance, and we remain a rather white Northern and European environment. We are improving at the Ph.D. and postdoc level with co-workers from Asia and Africa, but wish to work more on global inclusiveness. To the annual division retreats, typically 1-2 days per year, all co-workers are invited, including fellows and guests. These well-attended meetings provide opportunities to discuss work environment and division strategies.

The department trains research integrity and research ethics and fosters integrated research. Our annual research coordination meetings aim to meet new research grant calls across the individual backgrounds and sub disciplines of our researchers. The focus of these meetings is on communicating and sharing approaches that enable identifying new topical constellations. Both divisions run a higher seminar series to discuss new research, hear thought leaders in our core fields, and to integrate Ph.D. students and postdocs into a critical and understanding community of scholars. We work actively with the quality and the variety of our staff. We foster competence building of our young and mid-career scholars to meet the constraints of postdoc and temporary researcher employments (e.g., teaching experience, language, pedagogical, and management training). Development talks and performance reviews are offered annually to all our co-workers. Both divisions maintain a collegial leadership structure. Our steering groups are composed of representatives of all levels of employment, faculty, postdocs/researchers, Ph.D. students, and administration. Meetings are held two or three times per term.

The Division of History drafts five-year strategic plans since 2005, so far 2007-2012, 2012-2017, and 2017-2022. Strategy work has helped us think deeply and collaboratively on who we are, what we can become, and what difference we can make, to historical knowledge, to society, to KTH, and to the department as a leader of institutional development in the humanities. History also regularly reports on its activities in inclusive biennial division reports (most recently 2017-2018, published 2019).

The current faculty situation:

Philosophy: The current faculty consists of two full professors (male) and two associate professors (1 male, 1 female). A full professor (male) retired in 2018. Age-wise, the span is 46-52. We expect that the female lecturer will be promoted to full professor within 2-3 years. Given the age profile, we need to recruit younger researchers.

History: The current faculty consists of 3 full professors, 1 in Environmental History (M 1956, retiring in two to five years), 2 in History of Technology (F 1968, M 1973), and 2 associate professors, 1 in Science and Technology Studies with Historical Orientation (F 1966), and 1 in Environmental History (M 1966, also director of the EHL).

The department's current faculty is unbalanced with regard to gender, a situation to be relieved through promotion and conscious recruitment. Faculty is balanced in relation to disciplinary orientation. It provides skills and capacity to maintain supervision, research leadership, and abilities to think and act strategically. However, these capacities rest more on individual properties of our few faculty than on its collective size, which is modest in relation to the total staff of 87 employed through 2019, including 23 Ph.D. students, 24 researchers, 11 postdocs, 13 research engineers, 2 guest professors, 4 adjunct professors and 4 administrators. We have made up for this imbalance by hiring guest professorships to the department, and by affiliating professors and adjunct professors.

We have submitted proposals to announce permanent positions in Ethics, in History of Science, and in Environmental Humanities with Historical Orientation, all on the associate professor level. The process for hiring new faculty rests largely on the amount of long-term core funding and the number of long-term teaching commissions – none of which we have to a considerable extent. It is typically not considered desirable to hire new faculty based on external funding, and nor is there a substantial relationship be-tween growth of external competitive funding and the size of core funds.

Recruitment of Ph.D. students follows KTH's formalized procedures, which ensure that principles of diversity and equality are maintained. Recruitment committees are formed by a gender-balanced and position-balanced group of colleagues. For new faculty, recruitment follows a strictly prescribed process-based almost entirely on external evaluation. Post-docs and researchers are exclusively project-funded. To avoid unbalanced hiring to projects, we involve larger circles of colleagues in the selection process. Project leaders are informed and aware that a hiring process must have a balanced committee in place, often including non-project members for the interviews of short-listed candidates.

The KTH Environmental Humanities Laboratory (EHL) (founded Dec 2011) extends beyond the ordinary research organization at the Division of History. The EHL brings humanities and social science research to bear upon socio-ecological challenges and fosters just sustainability. It foments transdisciplinary research, training, and public engagement and has become a global player in the new field of the environmental humanities, with an international network of academic and societal collaborations across all continents. The EHL's areas of action include research on environmental change and social innovations, environmental justice, ecological democracy, and environmentalist movements; co-publishing the International Journal of Environmental Humanities (Duke Univ Press); training in environmental humanities, political ecology and visual studies; and outreach activities involving students, civil society organizations, policymakers, and the public. Initiatives include the annual Stockholm Archipelago Lecture, the CrossCuts Film Festival; the organization of two large conferences (> 500 participants); and the public environmental humanities projects on climate change in the city and toxic autobiographies. Around thirty scholars have spent research time with the lab.

The Posthumanities Hub joined the Division of History in 2018. The Hub links to artistic research & design, with strong outreach; it fosters and experiments with untraditional formats, like film and fiction, stakeholder engagement, and interaction with social, popular movements; it maintains unique international networks; it develops, transforms, and supplements the profile and brand of KTH as a technical university, to enhance attractivity, especially among potential female students, to create new pools of talent.

Both Lab and Hub have been growing organically, mainly through external funding. The EHL was made possible by a private donation and is now supported by KTH core funding. The Posthumanities Hub is funded through a guest professorship which KTH sup-ports for 3 years, and by externally funded projects. These infrastructures need maintenance, i.e., funding, for internal organization, event coordination, communication, and web maintenance, for inviting guests and for technical equipment.

The department aims to develop its faculty and strengthen its collaboration within KTH. It will work towards an increased role of the humanities at KTH, both in research, through an established platform of humanities and social sciences, and in undergraduate teaching, through a Master's program in the humanities developed in collaboration with partners at KTH. To reach these goals, we will work strategically with the organization and solidify our funding base, including expanded EU funding.

Philosophy: Growth. Increase national and internal interdisciplinary collaborations with an eye to wider outreach and societal impact. Aspire to strengthen position to be the leading Scandinavian hub for technology-centered philosophy.

History: We follow our current strategy: managing growth and consolidation; build up faculty and plan for the generational shift; work towards implementing multi- and post-disciplinarity at the division and department structure while maintaining its profile; maintain strength, output, visibility, and impact; increase cooperation with non-university partners; develop the publication strategy; sustain external funding flows (by increasing the share of EU funding); tap into new funding sources for the EHL; strive for a larger role in undergraduate education in cooperation with KTH partners, e.g. by opening up fields connecting science/technology to the wider field of integrated humanities.

KTH's Development Plan 2018-2023 envisions an "integrated KTH", "strengthened by the fact that all study and research programs are collected under a common scientific faculty that, in addition to classic technical fields, also covers natural sciences, life sciences, architecture and design as well as the humanities, social sciences and learning" (p. 6). "Among technical universities, KTH, in particular, has the potential to contribute in the field of sustainability, having the conditions for taking a holistic view and systematic approach" (p. 12).

The strategic vision for our department is predicated on the clear articulation of humanities and social sciences as part of the future KTH. Department members have collaborated in the presidential initiative HUMSAM@KTH that worked towards implementing humanities and social sciences research and teaching at KTH (a first report delivered in November 2018). This ongoing conversation needs fora where it can be discussed and where a more advanced articulation of the presence of non-technical fields of knowledge can be pursued. In our understanding, the future of the humanities and social sciences at KTH should be considered an overall strategic interest for the university. It should also be a core feature of the strategic vision of the ABE school.

The Department is led by a head from one division and a vice-head from the other divisions. Leadership alternates between the two divisions, as does responsibility for the Ph.D. program. There is no advisory group on the departmental level; each division has a steering group with wide representation. Monthly work-place meetings are held on the division level, as are the division retreats, research, and strategy meetings. Ph.D. students are organized on different levels with a focus on the division level, and with representation in accordance with KTH recommendations. Although line management is strong, the divisions' steering groups work to form a consensus that the heads of division use for decision-making. In practice, a collegial steering structure exists in the department.

The Department is situated in an academic environment and a research (funding) structure in which both research and publication-quality control is performed externally, through peer review, since all our research is externally funded. We have worked on publication strategies on the division level, and we aspire to publish our work in highly ranked journals, possibly open access. This is now facilitated by KTH centrally, through funding by KTH's library. Our Ph.D. education comprises regular course evaluations and annual supervisor colloquia. We maintain evaluation routines of mid-term and final seminars in Ph.D. education, inviting external reviewers. The publication formats of Ph.D. theses have changed to the compilation thesis as the default. The compilation has become more common in History and is obligatory in Philosophy.

Philosophy: The division's main quality strategy for research and research dissemination is its emphasis on publication in international peer-reviewed journals. The weekly research seminar is an important part of the quality process, as most research papers pass through the seminar. Each semester the researchers meet to discuss upcoming projects and funding calls, with the ambition to provide support and to find common interests.

History: The division has institutionalized work with project preparation and vetting, to secure maximum transparency and participation and to allow for coordination among upcoming ideas and external networks. This work is led by a designated Officer of research planning and coordination, currently also Vice-Head of Division. Some small core funding pays for extraordinary costs in preparing grant proposals. A vetting form is used to ensure that projects are acceptable for submission. Internal quality work on texts has decreased over the years, demanding more attention in the future.

5. Interaction between research and teaching

The department teaches comparably little on the undergraduate level, both BSc and MSc. We teach mostly elective and a few obligatory courses. Few courses are part of programs. Accordingly, student numbers are rather low in most of the elective courses.

Philosophy teaches ethics, philosophy of risk, decision theory, philosophy of mathematics, and research ethics. Its course, Theory and Methods of Science (TaMoS) is mandatory in some master programs (ca. 1300 students per year). All the courses are closely tied to the area of specialization of the teacher. History teaches basic courses in the history of science and technology and environmental history, informed by current STS and environmental humanities perspectives. Special thematic focus courses are, e.g., Gender & Technology; Energy & Society. The course Swedish Society, Culture and Industry in a Historical Perspective is an elective but extremely popular course offering knowledge among exchange students on their new country of residence, its history, society, culture, and other features (ca. 350 students per year). Some of our teaching (e.g., Energy & Geopolitics; Media, Technology and Culture; Science Goes Fiction; Energy Systems in Society; Computer History) is tightly connected to

the research. Examples are taken straight from empirical and theoretical work published by the teaching staff. An example of how teaching fuses with research is the recent publication of a textbook for the Energy & Geopolitics course (Energy and Geopolitics by Per Högselius, Routledge 2018), which integrates teaching preparations with research results from the division's energy research. Accredited courses are relatively fixed; contents change according to course responsible teacher's expertise, while the intended learning outcomes are updated more rarely. We have established new courses according to research expertise (political ecology, environmental humanities, Environment, and Society in a Changing Arctic).

Doctoral training and supervision are provided entirely by core-funding and sometimes by project funding (for fully funded Ph.D. students), which means that teaching is very closely related to research, including extracurricular summer schools, etc.

6. Impact and engagement in society

The department engages in the societal debate through communication and outreach, collaboration, and policy advice. We work with civil society at large, less so individual sectors, industries, or companies. We employ and foster the bottom-up perspectives of activists and communal/regional stakeholders, and we work towards communal, national, and international policy change. Besides, our teaching directly affects future engineers who choose our courses.

Philosophy: A great portion of the division's environmental research is of direct relevance to environmental policy and decision-making. This applies not the least to research conducted within the projects Sea-Rims (Formas, 2017-2021), Ethics in biodiversity offsetting (Naturvårdsverket, 2018-2020), Mind the Gap (Formas, 2016-2018), and Environmental co-benefits (2018-2019). A central aim of Sea-Rims (Formas) is to produce ethical analyses and tools that can be used to assist municipalities and county administrative boards in their climate adaptation decision-making. The project "Environmental co-benefits" resulted in a review article synthesizing the rapidly expanding knowledge of climate co-benefits that can improve decision making in the direction of increased sustainability. A core aim of "Mind the Gap" was to build knowledge among environmental decision-makers of how denial of scientific evidence and knowledge can be used to deliberately slow down the environmental policy-process.

History: The division has been increasingly active in current environmental and Anthropocene media debates, adding a humanities perspective to questions of climate change, individual and collective consumption patterns, or resource extraction industries. Our research includes stakeholder perspectives of, e.g., NGOs and local and indigenous peoples (e.g., Mistra Arctic Futures; REXSAC; Toxic

Biographies). The EHL and the Posthumanities Hub highlight performative research in formats of art, museum exhibitions, and activism. The Making Universities Matter (MUM) platform (Vinnova) continues the research policy work that Mats Benner (KTH/Lund U) and Sverker Sörlin (KTH) conducted in the Swedish Research advisory board. A most tangible outcome of such policy advice was the 2016 research bill with its current scheme of flexible, integrative calls from the Swedish research councils.

The department contributes debate articles and popular-science essays in the (Swedish) media, radio, TV, public panels, and seminars. Topics are, e.g., science skepticism, science/climate denial, and current Anthropocene challenges.

Philosophy: Several of the division's research projects directly address sustainability and the SDGs, see above. Mistra Biotech is an eight-year interdisciplinary research program that focuses on the use of biotechnology in crop and livestock breeding, including regulatory and ethical aspects of GMO introductions. One of the core aims of Mistra Biotech is to contribute to more sustainable and competitive agriculture, contributing to several of the SDGs, perhaps most notably SDG 2 (zero hunger) and SDG 15 (life on land). Crucially, not only the ecological aspects of sustainable development are covered by the division's research. Social sustainability aspects are addressed in several of our Ph.D. projects, perhaps most clearly in a project funded by the Swedish Road Administration focusing on Vision Zero in road traffic safety (SDG 3, good health and well-being) and a project conducted in collaboration with the Swedish Defence University focusing on gender aspects in defense systems (SDG 5, gender equality). One faculty member (Edvardsson Björnberg) and two senior researchers (Wikman Svahn, Karlsson) have environmental and climate-related issues as core research. Most of the externally funded projects (> 80%) relate directly to SDGs.

History: A majority of the division's research addresses social and environmental sustainability, not least since the foundation of the EHL in 2011 as a direct response to the increasing need and attention for broader environmental research. The EHL led an international team of researchers from Brazil, the United States, Turkey, Italy, and Sweden to investigate social innovations developed by civil society organizations and municipalities in five metropolitan areas in the Formas-funded project Occupy Climate Change (OCC!) on societal responses to climate change. Other projects explore the argumentative structures of climate non-action or sustainable travel ("The Travelling Scientist" project and blog). The division acts as ABE's representative in a research project on KTH's climate framework of carbon reduction. We carry out projects on natural resource access and use, e.g., Arctic mining and

sustainable development, or water management research linked to the KTH Water Center. Most of our externally funded projects (> 80%) relate to SDGs.

Impact cases:

(1) The Mistra Biotech research program has generated a series of peer-reviewed articles addressing the EU legislation on GMOs (Edvardsson Björnberg, Hansson). The main findings of these articles have been presented at various venues in Sweden, among them the Swedish Gene Technology Advisory Board. They also form part of a growing body of international research questioning the present EU legislation on the grounds of legal clarity, consistency, and proportionality. Possible amendments to the legislation identified by the researchers and co-authors are debated in several EU member states.

(2) Crosscuts Stockholm Environmental Humanities Festival for Film & Text is a re-current international and transdisciplinary festival for documentary film and debate that took place in 2018 and 2019 at BioRio, one of Stockholm's most prominent program cinemas, with more than 1000 participants. The festival explores current environmental topics, e.g., climate change, resource extraction, urban environments, environmental activism, and filmmaking (Armiero, von Heland, Jonsson, KTH, and Miyase Christensen, Stockholm U, in collaboration with Media and Communication Studies, SU, and Filmhuset/Cinemateket. The festival brings performative research to larger audiences and develops knowledge and practice around film as a research tool ("Visual humanities", a Formas-funded research project at the History Division). Among the ca. 20 films shown was the "cinematic ethnography" One Table, Two Elephants by division researchers von Heland and Ernstson (2018). Two "masterclasses" were held on activism and on filmmaking. A Short film competition (international jury) and a film-review session "Annals of Crosscuts" exercise peer-review to develop film-as-research.

(3) CHAQ Creating Cultural Heritage in Antarctica and CHAQ2020 Argentinean-Swedish expedition: CHAQ explores the production, conservation, and use of cultural heritage in Antarctica (PI van der Watt, KTH). CHAQ2020 is an Argentinean-Swedish expedition (Jan-Feb 2020) to the historical remains of the First Swedish Antarctic Expedition 1901-1904 (PI Avango, LTU/KTH & Lindström, KTH). Long-term work on polar social science and humanities resulted in a leading research community of cultural heritage studies at the History Division the 1990s, maintained by research and leadership in Sweden's IPY Commission 2006-09 and by large research programs (Mistra/Nordforsk) in the 2010s, leading to the commissioning of the expedition by the Swedish National Heritage Board. To chart the terrain, different technologies of documentation were employed (drone-footage, 3D technology, documentary re-photography). Together, project and expedition affected both policy and science diplomacy: CHAQ2020 was discussed at the highest

international diplomatic level, the Antarctic Treaty Consultative Meeting, in 2019. Results are expected to influence policy briefs for the 2020 meeting in Finland. CHAQ will help create national guidelines for Swedish Antarctic heritage, involving several state agencies (Swedish National Heritage Board, Swedish Polar Research Secretariat, Department of Education, and Department of Foreign Affairs). In planning is a documentary film about climate change impacts at the Antarctic Peninsula; and an exhibition at the Argentinean research station Esperanza.

We aim to expand work with non-academic partners (communities, local authorities, governmental agencies, NGOs, and companies). To strengthen collaboration on the faculty level, we aim to adjunct and affiliate partners from the non-academic sectors.

Department of Real Estate and Construction Management

1. Overall analysis and conclusion; Strength and development areas

The Department of Real Estate and Construction Management consists of five divisions, each with specific strengths and weaknesses. The research at the department is applied and problem-oriented. Knowledge gaps are identified in relation to both new and traditional societal and industry challenges, and to technology developments that are relevant for this field. At a general department level, the following strengths and weaknesses have been identified:

Strengths:

- Multidisciplinary research environment
- Applied topics relevant to the sector
- Researchers that teach / teachers that do research
- A positive trend in publishing
- Process of moving to a new office and reorganizing almost finished: Synergy-effects seen in more cooperation between researchers, divisions and with other departments at ABE and KTH in applications for funding and in research/papers
- National cooperation in research (examples: Chalmers university of technology, Luleå university of technology, Lund university of technology, Stockholm University, Uppsala University, University of Gävle, Mid Sweden University, Mälardalen university)
- International cooperation in research (examples: Stanford/US, Aalto University and Åbo Akademi/Finland, Aalborg University/Denmark, Norwegian university of life sciences/Norway, University of Twente/Netherlands, NUS/Singapore, École Polytechnique Fédérale de Lausanne/Switzerland
- International accreditation of education (master program RECM)
- Membership in international field-oriented associations (examples: The Royal Institution of Chartered Surveyors (RICS), European Academy of Land Use and Development (EALD), International Association of Geodesy (IAG))

Weaknesses:

- Small units within different disciplines (minimum size is important to balance in each field)
- Skewness in positions and resources (in relationship faculty/researchers, which makes researchers focusing on teaching; in different types of financing, which makes recruitment for obtaining a better balance difficult)

- Few EU-projects
- A negative trend in external financing of research
- Low ranked journals in some of the applied research fields
- Work with referrals (in Swedish: remisser) on Swedish real estate law is not seen in statistics on the department´s outcome (has a large impact in society)
- Loss of relations to practitioners in the sector due to generation shift as it is essential for applied research that there is a close connection between research, teaching, and industry collaborations

The Department of Real Estate and Construction Management has a long tradition of – and a large number of ongoing projects involving – a collaboration with industry, Swedish authorities, and other organizations as well as the public, in matters concerning the development of the built environment.

The main research infrastructure consists of different databases and a number of geodetic instruments mostly used in teaching but also for research purposes. The department had – until 2018 – a local BIM-lab.

Several of the sustainable development goals are dealt with in the research of the department and its publications. According to the bibliometrics, the goals that are present in the highest number of publications are SDG 13, 11, 14, and 9, i.e., Climate action, Sustainable cities and communities, Life below water, and Industry, innovation, and infrastructure. It is estimated that 40-60% of the department's research is related to sustainable development, or somewhat higher in specific research groups.

2. Research profile

The Department of Real Estate and Construction Management is one of six departments at the School of Architecture and the Built Environment. It is one of the smallest departments at the school (in 2019) in a total of 64 employees and yearly revenue of approx. 80 million SEK with about 50% generated by teaching activities and 50% from different kinds of research funding.

The department presently consists of five divisions: Real Estate Planning and Land Law; Real Estate Economics and Finance; Real Estate Business and Financial Systems; Construction and Facilities Management; and Geodesy and Satellite Positioning (The Division of Geodesy and Satellite Positioning was in 2012 and until January 2018 a part of the Department of Urban Planning and the Built Environment). The divisions are all working with applied research concerning the built environment, but are active in different academic disciplines. Hereafter in the document, the disciplinary structure is described instead of an organizational structure, and research at the division Real Estate Economics and Finance, as well as Real Estate Business and Financial Systems, are treated under the same heading: Real Estate Economics, Finance, and Business studies.

The Department also hosts the Centre for Construction Efficiency (CBE). This is a platform for collaboration and development between institutions, industry, and society. CBE creates a cross-disciplinary and internationally renowned research environment, as well as conducts research and development projects. The projects contribute to safer working environments, effective construction processes, and strengthened international competitiveness. The Head of Centre is also employed as a full professor at the Department. CBE is not commented on more in this report as the main focus should be on research activities within the KTH main organization.

A recent survey among the employed faculty and researchers (including post-docs but not doctoral students) at the Department of Real Estate and Construction Management displays the main research interests. As the size of the words in this cloud illustrates frequencies, it also gives a perspective of the size of the divisions in number of individuals.

- The Division of Real Estate Planning and Land Law engages in teaching and research on how rights associated with land use and real property can be established and/or adapted in order to facilitate desirable societal development, for example, the construction of buildings with complementary infrastructure, or the conservation and protection of valuable natural areas.
- The Division of Real Estate Economics and Finance delivers teaching and research concerning economics and finance applied to the thematic areas of building and real estate. Research is mainly based on economic theory, but also takes into consideration the interaction between different markets related to the thematic areas as well as macroeconomic variables.
- The Division of Real Estate Business and Financial Systems engages in teaching and research applied to the thematic areas of building, real estate, and the function of financial systems. Research at the division is mostly based on theories and traditions within the field of business studies. The main focus of study is the unit of the firm as well as consumer studies.
- The Division of Construction and Facilities Management performs education and research in project management, collaboration, communication, information management, procurement, and construction logistics. The research field covers the organization and management of the entire construction process, from concept and design to production and maintenance. The focus is on project members' communication and information management.
- The Division of Geodesy and Satellite Positioning delivers teaching and research that includes both theoretical and applied areas of geodesy. Priority areas are applied geodesy with specialization in surveying – including surveying for cadaster and for map production – as well as regional geoid determination and processing/analysis of space geodetic observations from various satellite systems, e.g., for climate-related research.

Central research questions and themes, knowledge gaps addressed, and main research activities at the department:

Real Estate Planning and Land Law

The subject area comprises the formation of real property units and real property systems, together with associated structures of land use and developments. The focus of the research is on society's demands for rational and appropriately designed property units and other land-based property rights systems, as well as methods for transforming property division and property rights systems.

This general description can be broken down into two sub-areas: property division and property rights systems; and land development processes.

- The segment of property division and property rights systems encompasses theories regarding society's needs and requirements for rational and appropriately designed property units and other land-related property rights systems, as well as efficient methods for transforming property division and property rights. This also includes questions regarding real property registration and real property information.
- The segment of land development processes focuses on theories and methods for alteration and protection of land use in the light of technical, legal, economic, and political requirements.

In recent years, the subject area has developed towards focusing on institutional rules for land-related rights – and transformations of these rights. Based on the concrete research projects carried out during the last years, this can be broken down into five distinct branches of research. For some of these areas, there are research teams with senior researchers and Ph.D. students, although research teams can also be formed more temporarily for specific projects.

In the area covering institutional aspects of real property and property rights systems, a number of international studies have been conducted, both at the Nordic and European levels, concerning systems for ownership, property division, and property rights. These include studies dealing with real property registration, different tenure forms for housing, legal institutions for ownership apartments, models, and institutions for real property transactions and property formation. At the national level, a partially new field of research has developed regarding property rights design for three-dimensional real property employment, which has been revived by the ongoing debate and reforms on three-dimensional property division and ownership apartment properties.

A number of international projects with comparative analysis of planning and permit systems have also been carried out in the area of planning, plan implementation, and land use permissions, several of which have led to legal reforms of the planning and building legislation. Further, research projects have studied and analyzed legal and economic tools for plan implementation in the field of land development. This

branch also includes research on operative institutional systems for housing provision, where organizational and economic aspects outside of the planning system may be crucial.

In the branch concerning responsibility for and financing of infrastructure, studies have been conducted on the distribution of land development profits. A number of projects, some at the international level, have also addressed the issue of public value capture, where public investments in infrastructure and services lead to rising land values for urban properties and developments.

In the area of land acquisition and compensation, procedural rules and forms in planning and land acquisition have been studied, as well as forms for the protection and preservation of valuable natural areas and cultural-historical constructions. Several different projects have dealt with compensation issues in the case of compulsory acquisitions and disposition restrictions in the wake of the 2010 legal reform of the compensation system in the Expropriation Act. In order for the real estate and credit markets to function effectively, there is a need for well-designed legal institutions for transactions of ownership, granting property rights such as leasehold or rent, mortgage, as well as financing of real property and housing. This is the focus of the fifth element in real estate planning and land law research. Several studies have focused here on housing and rental legislation, various forms of right of use to real property, transfers of real property, etc. in the Swedish Land Code.

Real Estate Economics, Finance, and Business studies

The research profile can be described based on several themes. These include real estate economics and finance, housing economics, real options, and construction economics. The research focuses on commercial real estate markets and housing markets. Furthermore, the research studies, both direct and indirect real estate markets.

The research is mainly based on economic theory but is applied to the division's thematic areas. Since the real estate markets are highly integrated with the financial markets and the overall macroeconomic environment, the research also takes into consideration the interaction between the different markets and macroeconomic variables.

The research in real estate economics and finance is based on quantitative research methods, with a focus on empirical research aiming at estimating causal relationships. However, some research also focuses on the development of theoretical mathematical models of real estate markets. Forecasting of property prices and quantification of property price risks also belong to the research agenda. Research on securitized (listed) real estate markets has grown in importance, where applied financial econometrics research on the price and return data of public REITs and listed real estate sector indexes are at focus.

In the area of real estate, housing, and urban economics, there are a large number of social challenges. These concern questions about the functioning of the housing market, housing affordability, housing

shortage, and over-indebtedness, and partly how the real estate sector should respond to the climate threat. In addition, there exists new research that applies real options models, e.g., for land valuation.

Research in real estate business is based on a combination of qualitative and quantitative methods, and among areas of study are entrepreneurship, market analysis and marketing, sustainability, property management, urban and regional development, and organization. Today, the real estate market is closely interwoven with the financial sector. This connection is also studied, especially in the light of the digitalization society is undergoing. The different actors in the financial system, and the way they interact with the real estate sector in different stages, thus become important. The debt issue is, for example, still important to analyze as there has been a transfer of risk from the public to the private. The issue of financial sustainability is as important as economic, ecological, and social sustainability.

Digitization can partly be seen as an enabler for streamlining property management and construction processes, but digitization can also be seen as a change that will have a significant impact on how we use our properties and thus our cities.

Construction and Facilities Management

The main focus for studies in construction management during the period has been change, innovation, and sustainability, in particular how client/owner driven innovation and change can support a more efficient and sustainable built environment.

Within the field of construction management, four interdependent "drivers" for innovation, organizational change, and increased efficiency and sustainability have been explored during this period. Most research has taken the perspective of the public client/owner. However, also, the contractor, consultant, and societal perspectives have been addressed.

The development of new technologies, in particular BIM, and their effects on construction efficiency and productivity has been studied. During the last few years, the digitalization of/in the built environment sector has been intensified, and the need for scientific knowledge on digitalization is extensive. Several projects have focused on digitalization and its effects.

New collaborative project work practices attract much interest from both industry and society. How can such relations be designed, and what are the effects? Research projects have focused on the development, implementation, and effects of collaborative contracting in projects, but also on long-term inter-organizational development, business networks, and collaborative/relational methods for knowledge integration. Projects have also applied critical perspectives on project management research.

New technologies and sustainability goals challenge institutionalized organizational practices in the built environment. There is a need to develop robust models for systematic innovation management in projects and permanent organizations as well as on the industry level. Research-based knowledge of

innovation processes and practices in this complex project-based sector is essential to guide this development.

Procurement, and in particular public procurement, is often seen as a tool for client-driven change, innovation, and sustainability in the construction industry. How can procurement strategies and requirements be designed, and what are the effects of different procurement strategies and requirements?

Some of the research projects are multidisciplinary and carried out by teams involving researchers from other disciplines, such as information systems, architecture, and planning. Competences in economics, facility management, and legal issues are found within the department. Competence in Construction IT is currently weak since the professor retired a year ago, and no new recruitment has been made. This is a weakness that can be handled through collaborations with other departments and universities and/or recruitment.

The research in the field of real estate management is applied and problem-oriented, which implies that knowledge gaps arise in relation to new societal challenges or technological developments that are relevant to this field. Sustainability has been the main theme during this period, especially how economic incentives influence decision-making and the economic effects of various sustainability initiatives. Consumer/tenant perspectives, owner perspectives, and societal perspectives have all been addressed in this research.

The main contribution areas in ecological sustainability are adoption by housing cooperatives of renewable energy technology such as solar photovoltaics, tenant and consumer experiences, and preferences in relation to green building: what values they perceive in terms of quality and branding and how this affects purchasing decisions and prices.

Main contributions areas in social sustainability are: housing owners' strategies for building social sustainability (rental policies, owner incentives, financial viability from a societal point of view); conversion of rental apartments to housing cooperatives and private ownership in low-income areas – legal aspects, feasibility, integration, prices and neighborhood effects; sustainable renovation strategies in 1960s housing areas; urban development work in a segregated city with filtered housing areas; municipal housing social programs; effects of rental policies on discrimination and segregation; gender aspects in real estate management (collaboration with Malmö University).

Related to economic sustainability, research has addressed: maintenance strategies; business development in commercial real estate management (with Malmö University); outsourcing and procurement of Facilities Management and maintenance services (two Ph.D. projects with Luleå University of Technology on the road and railway maintenance in the Swedish Transport Administration, including a comparison with practices in the building sector); how to efficiently transfer knowledge from the building use, operations and management phase to construction projects. A Ph.D.

project investigates knowledge transfer in municipal school building and renovation, a field that will entail substantial public investments in the coming years.

In the last few years, digitalization has emerged as a major challenge and potential driver of change in the real estate sector. Several projects with a digitalization focus have been started since 2017, focusing on real estate owners' strategies and innovation eco-systems in this field. The first important output was a licentiate thesis in 2020. Following societal challenges and developments related to climate goals, digitalization, and social sustainability, real estate owners, and construction clients have raised their innovation ambitions. To develop the innovation management capabilities in such organizations and their ecosystems is crucial to increase innovation rates in the real estate and construction sector in general. This question is addressed both in the digitalization projects and in a collaborative project involving three large property owners, both private and public.

Geodesy and Satellite Positioning

The Division of Geodesy and Satellite Positioning conducts research in both theoretical and applied geodesy contributing to climate change-related studies and digitalization of the planning and building process. The main topics are monitoring geodynamic phenomena (land and sea-level rise), geoid determination, development of methods for precise positioning, and collection of geographical data using terrestrial and satellite sensors and realization of geodetic reference systems on project level. The main research activities are mainly theoretical and numerical analyses, to a smaller extent, experimental collection of data (measurements).

Contributions to the advancement of state of the art within the research fields of the department:

Due to the ambition to respond to emerging challenges, developments, and needs in society and industry, new empirical phenomena are continuously being explored with the different disciplinary tools used in the department. Below, each main research field is commented upon.

Planning and Land Law

Several contributions have been achieved in the field of digitalization of land development in the legal dimension regarding the material and procedural provisions in real property law. These are early and initial outcomes in the first phases regarding legal reforms of real property law as requirements for digitalization.

Regarding approach and design: Within the field of real estate planning and land law, recent research indicates more accentuated connection to theories in the interfaces between law and microeconomic theory (law and economics), as well as between law and theories of distributive justice (law and

philosophy). In addition to these two approaches, there is, of course, also more traditional legal research (legal dogmatic method).

Economics, Finance, and Business Studies

Based on the articles that have been published in recent years, it can be stated that the research conducted in the department is on or near the research front. This is especially true in housing economics, REITs, and in the area of real options.

A major contribution is also to expand and integrate multiple theoretical research areas into applied real estate and banking research. For instance, gender research in banking, human-computer interaction in banking, finance, and management of real estate firms, etc.

Construction and Facilities Management

Novel and well-recognized research are currently carried out in the fields of innovation, business networks, knowledge integration, and procurement. The department was early in performing research on the implementation of digital technology, collaborative work practices, and inter-organizational integration, fields that have increased in attraction. The research in the fields of innovation and procurement has substantially developed during the last few years due to recruitment and reorganization, and it has turned into a strong, growing, and promising area of research. There is potential to grow further and develop into an internationally leading group in construction innovation research. For this to happen, international collaboration and academic publishing, as well as additional recruitment, is crucial.

Geodesy

The division has developed a specific method for precise geoid determination. This method, often called the KTH method, is based on the least-squares modification of Stokes' formula by combining global gravitational models, ground gravity measurements, a high-resolution digital terrain model, and GNSS-levelling data. The method has been used to compute the Swedish national geoid model used in a practical GNSS survey. In addition, this method was successfully applied in the determination of several regional geoid models: the Baltic countries, Greece, Iran, Sudan, Zambia, Ethiopia, Tanzania, Serbia, Moldova, part of Turkey, and it was used by the Nordic geodetic Commission in the NKG geoid model 2015.

Regional land uplift modeling from using satellite gravimetry data: the division developed a method to determine a gravimetric land uplift model using satellite gravity missions (GRACE). The land uplift model plays an important role in the present day's processes related to the Earth system. Studying the land uplift rate allows us to investigate the long-term development of the Earth's shape, interior, and gravity field, which affects a vast number of other phenomena such as those related to the prediction of

climate change. This method has been employed to model the land uplift in Fennoscandia and Laurentia successfully, and the division has plans to apply it in Greenland and Antarctica. The outcome of this research can contribute to practical/technical use in time-tagging precise vertical positions, e.g., GNSS leveling and calculate precise project-adopted geoid models and NRTK (network real-time kinematic) applications. In addition, the outcome of this study will help the estimation of sea-level change that needs the information on land uplift.

Earth's lithosphere modeling: the division has developed a novel gravimetric approach to determine different Earth's interior parameters such as crustal thickness depth, density, upper mantle viscosity, and density. The knowledge of Earth's interior parameters plays an important role in understanding the relationship between the geodynamic processes. Although, it is difficult to find an exact method that delivers a complete image of the Earth structure. However, gravimetric methods are alternative to provide images of the interior of the Earth. The developed technique can reveal adequate information about the solid Earth system, e.g., density variation, earthquake, and continental rifting.

Methods for improved GNSS positioning and navigation, as well as improved applications of high accuracy GNSS positioning: Research in this field includes for instance research on new methods for reliability analyses and data quality assessment in real network time kinematic (RTK) GNSS positioning, work which is important for providers of GNSS positioning services or augmentation systems at a national or global level. In addition, research carried out on the optimal design of geodetic GNSS-based networks, as well as optimization in deformation monitoring networks considering baseline correlations, is important. This research is relevant for applications of GNSS, for instance, for monitoring of land surface movements such as landslides and for deformation monitoring of large structures such as dams and bridges. The methods developed at KTH are being used in civil engineering consulting companies for such purposes.

Another research topic related to GNSS is the estimation and characterization of hardware biases in GNSS code and carrier phase observables. This research, carried out at KTH, led to the discovery of drifts in biases analyzed for a tablet, drifts that had not previously been known in the engineering community. The results of this work are beneficial for the increasing use of GNSS positioning with new platforms like smartphones and tablets, where characteristics of the biases are necessary for advanced GNSS positioning using methodologies like precise point positioning (PPP).

The division participated in the research project "Control network in the air" conducted in cooperation with Trafikverket, which resulted in a more effective method for the realization of the national reference system on the project level. The approach and surveying methods developed in this project have been applied to several large infrastructure construction projects. A new research project with the goal to refine this realization started in 2019 with the division as one of the participants.

Quality and quantity of contributions to the body of scientific knowledge:

Real Estate Planning and Land Law

Given the limitations of faculty, the division produces a vast amount of internationally and nationally high-quality articles, conference papers, research reports, books, etc. However, much of the research output within real estate planning and land law is not captured by the applied bibliometric tools, with journal impact and citation indexes. These instruments fail to capture a number of important research output products and their impacts, e.g.:

- Ekbäck, Peter (2017) Mark- och fastighetsrättens utveckling i Sverige. En rättshistorisk orientering med betoning på fastighetsbildning och infrastruktur. [Development of Law on Land and Real Estate in Sweden. A Legal-Historical Orientation with Emphasis on Real Property Formation and Infrastructure.] TRITA-FOB-Rapport 2017-1. Div. of Real Estate Planning and Land Law, KTH. This is a comprehensive and voluminous work of more than 500 pages, covering the Swedish legal historical development in the field of Real Estate Planning and Land Law, from the medieval up to present, which is requested both nationally and by other Nordic countries for research and educational purposes.

There may be several reasons for this inadvertence. Firstly, the legal domain is by its very nature specific and defined on a national basis, a fact that particularly true for the area of real property law. This result in that publication are not delimited to articles in international journals. On the contrary, a large portion of the output is in the forms of reports and books. Secondly, the standard language for research publications within the legal discipline is not English, but rather Swedish.

Real Estate Economics, Finance and Business studies

The quality of the research articles published in real estate economics, finance, and business studies during the period has been good, but the quantity has been relatively low in relation to the number of staff. This is partly because there has been a generational shift in recent years involving the retirement of several scholars within these research fields, and because the researchers at the department are primarily involved in teaching (also somewhat due to the generation shift and slowness in the recruitment process).

Construction and Facilities Management

During the last few years, the division has expanded via external funding, extensive collaboration both nationally and internationally, and recruitment. The division faculty is now one of the leading research groups in Sweden in this field. Currently, there are more than ten externally funded PhD-projects

running with supervisors from the department. Some of the projects are managed from KTH; others are collaborations with other universities.

Research in project communication and construction project management is published as scientific articles in reputable journals and conference papers, but there is improvement potential. Due to the applied focus, some important research pieces have primarily been published as reports in Swedish. In addition, a significant impact has been made in the standardization work, including standards for open BIM/Building SMART/IFC and Collaborative business relationship management (SS ISO-44001). This reflects a tension between the demand for results that gain societal impact (and the research funding sources) and the academic publishing ambitions, a tendency which is also often found in the domain of architecture. It should further be noted that several projects in the project communication and construction project management fields are recently started and have not yet resulted in publications.

The research in real estate management is published as scientific articles in reputable journals and conference papers, but this aspect has an improvement potential. Due to the applied focus, some research has primarily been published as reports in Swedish. It should further be noted that several projects in the real estate management field are recently started and have not yet resulted in journal publications. Further, several staff members active in this field have left KTH during this period while only one faculty member (a professor, on a 50% basis during 2016-2018) and two Ph.D. students have joined.

Geodesy and Satellite Positioning

The research team has succeeded to publish in many well-known and high-impact journals and national and international conferences. In addition, the publications attracted many audiences, and several workshops (about BIM) and five successful international summer schools about geoid determination were organized. In the period 2012 – 2019, the division of Geodesy and Satellite Positioning researchers have published almost 100 peer-reviewed scientific articles, and six Ph.D. students successfully completed their studies.

Engagement in national and international research collaboration within academia and its outcomes

Real Estate Planning and Land Law

The Division of Real Estate Planning and Land Law is at present initiator and coordinator of a Nordic network for collaboration in research and research education, involving Aalborg University (Denmark), Aalto University (Finland), Lund University (Sweden), and Norwegian University of Life Sciences (Norway).

A number of researchers at the division take part as members of the European Academy of Land Use and Development (EALD), which is an association for regularly scientific meetings in the form of symposia, publishes peer-reviewed scientific works, serves as a platform for the establishment of international research cooperation and supports activities with the aim of creating networks of various actors in the area of spatial development and soil protection.

The division is a member of the Advisory Board for Geodesy, Bavaria Academy of Sciences in Germany. The Advisory Board is a bridge between the Bavaria Academy of Sciences and the German Geodetic Commission (DGK). The board has six international members, covering the competence areas of high geodesy, engineering geodesy, land management, photogrammetry, and remote sensing, cartography, and geoinformatics.

The ADLAND project – Advancing collaborative research in responsible and smart land management in and for Africa – is a joint international research project, coordinated by the Technical University of Munich (TUM). The Division of Real Estate Planning and Land Law was one of six northern partners, where different research and curriculum development activities were directed towards a number of different African universities. The project ended in 2019, but negotiations for a new cycle are in progress.

The COST Action “Public Value Capture of Increasing Property Values” is funded by the European Cooperation in Science & Technology. It started in 2018 and is planned to run for a 4-year framework, with researchers from over 30 countries, including the Division of Real Estate Planning and Land Law. The project’s purpose is to explore the economic, social, geographical, planning, and legal aspects of optimizing the allocation of costs and benefits in urban settings. The project aims to use theoretical knowledge to provide a practical set of policy recommendations for local and regional societies faced with increasing property values and distributive justice dilemmas. Implementation of such tools could lead to a better balance between private and public considerations and to more and socially sustained societies.

The division is a partner in the EU-funded SUSDEV-project (Lifelong Learning for sustainable development), with the target to enhance the role of higher education institutions in ensuring sustainable development of industry and society, support of national “green policies” in partner countries, and promotion of "green culture" by means of lifelong learning.

The division has been involved in VERITAS (Structural development of the third cycle based on Salzburg principle), a Tempus-funded project which was launched in 2013 and ended in 2018. The project involved the development and establishment of 11 new doctoral programs at different universities in Armenia, where the division has been one of the lead partners.

The division participates in a SIDA-funded post-graduate project with Ardhi University (Tanzania) for 3 doctoral students, comprising joint supervisions, Ph.D. courses, and double degree examinations. The program ends in 2020, but negotiations for a new cycle is in progress.

Real Estate Economics, Finance, and Business studies

Over the years, researchers from the department have participated in a large number of conferences. There, research has been presented, and networks have been built. The networks have mainly been with other researchers in Europe, although there are exceptions. In recent years, networks have been developed with China, in particular.

The most important international research collaborations within the field of Real Estate Business studies are with Stanford University (USA), National University of Singapore (Singapore), Oslo University (Norway), and Åbo University (Finland). The collaboration with Stanford was built based on staff going from KTH to Stanford, and the collaboration with the National University of Singapore was built from student exchange.

National collaborations are numerous, and most research projects involve several other Swedish academic institutions.

The two divisions working within this research field also participates in a SIDA-funded post-graduate project with Ardhi University (Tanzania) for two doctoral students, comprising joint supervisions, Ph.D. courses, and double degree examinations. The program ends in 2020, but negotiations for a new cycle is in progress.

Construction and Facilities Management

An important collaborative arena during this period has been the national Strong Research Environment ProcSIBE (Procurement for Sustainable Innovation in the Built Environment, 2014-2020) funded by Formas (see also Impact cases). KTH has been a leading partner in this network, where the initial funding of 25 MSEK has increased to around 75 MSEK. A central part is a large collaborative research program with the Swedish Transport Administration, involving several Ph.D. students. The national collaboration ProcSIBE has thus been useful in providing funding, networks, and impact. This initiative originated in the collaborative organization Swedish Universities of the Built Environment, involving the four large technical universities.

The division is related to the IMP Group. This is an international research community engaging in industrial network research and involves several annual and biannual conferences and workshops, a Ph.D. collegium, and a journal forum within the Journal of Business and Industrial Marketing. One of our researchers is a board member of the IMP Group.

Researchers are connected to a European network of researchers studying innovation in the construction industry – ENRIC (European Network of Research on Innovation in Construction). Currently, the network involves eight countries and about 40 researchers.

Researchers have also participated in the Centre for Building Efficiency and collaborated with the twenty partnering organizations. This has enabled interactive workshops, co-funding, and a platform for longitudinal empirical research at Stockholm Royal Seaport in collaboration with Stockholm municipality and the developers and contractors active in the development of the new sustainable urban district. It has been useful for impact, network, co-learning, and funding.

An important network has been established through the large international ProcSIBE project "Implementation of Procurement Requirements for Sustainable Collaboration in Infrastructure Projects (Impres)". This project is a part of the Construction Climate Challenge, an initiative hosted by Volvo Construction Equipment, which has ensured wider dissemination of results. The Impres project has also been co-funded by the Mistra Carbon Exit program, which provides additional networks within academia, industry, and policy-making, both in Sweden and at the EU level. The Department's involvement in Mistra will continue if the program is granted funding for a second period.

The field has extensive collaboration with external actors, national and international universities, public and private companies as well as intermediates. Still, the international collaborations are relatively few and have until now only resulted in a few joint publications. Thus, developing and expanding international collaborations and increasing joint publications are identified as crucial activities, and the work to improve has already begun. At the moment, there are new collaborations initiated with UCL in the UK and Åbo Akademi University in Finland. Nordic research collaboration around procurement in the built environment has been initiated, and three meetings have been held 2018-2020, two of which at KTH.

During this period, researchers working with real estate management have participated in two national Strong Research Environments funded by Formas: SIRen (focusing on Sustainable renovation strategies) and ProcSIBE (Procurement for Sustainable Innovation in the Built Environment). These have been useful in providing funding, networks, and impact. Both these initiatives originated in the collaborative organization Swedish Universities of the Built Environment, involving the four large technical universities.

Participation in the Scientific Advisory Board for the large multiparty research project Mistra Inframaint and as a researcher in Mistra Carbon Exit has also provided important contacts with academia, practice, and the policy level.

As for bilateral relationships, there is, or have been, research collaboration with Malmö University (supervision of five Ph.D. candidates), Stockholm School of Economics (two research projects),

University of Technology Sydney (UTS) (two research projects), Twente University in the Netherlands (informal benchmarking, potential joint projects).

Geodesy and Satellite Positioning

In Geodesy, there is a strong tradition for collaboration because of large scale fieldwork, expensive satellite missions, and comprehensive data analyses. KTH-Geodesy participates in research cooperation with other universities in Sweden, e.g., Lund University and the Chalmers University of Technology. In addition, Lantmäteriet is a close partner in terms of research cooperation.

Internationally, we cooperate within the framework of the Nordic Geodetic Commission (NKG), as well as the International Association of Geodesy (IAG), where KTH staff members participate in, and contribute to, committees, working groups, workshops, research schools, etc. Taking an active part in the international research community also makes it possible to find partners for collaboration on international projects. KTH Geodesy cooperates with, e.g., the University of Stuttgart in Germany, École Polytechnique Fédérale de Lausanne (EPFL) in Switzerland, and the Technical University of Denmark (DTU) on research projects and applications for e.g., EU funding.

Through the EU Erasmus+ Program, the Geodesy Division also has close cooperation with geodetic institutions in Austria, Spain, Italy, Albania, Bosnia, Serbia, Armenia, Moldova, and Ukraine, as well as Central Asian countries.

The latest RAE at KTH was carried out in 2012. At that time, the Department was formed differently and only included the divisions Building and Real Estate Economics, Real Estate Planning and Land Law, and Project Communication, which means not all divisions presently included in the Department. In addition, the Centre for Banking and Finance (CEFIN, closed in 2017) was evaluated as a separate part, but belonging to the Unit of Assessment. The Centre focused only on research, and the staff is now relocated to the two divisions Real Estate Economics and Finance; and Real Estate Business and Financial Systems and is in the present RAE evaluated within the department. The Division of Geodesy joined the department in 2018 but has a long history at KTH.

For the Department of Real Estate and Construction Management (Unit of Assessment, UoA), the following recommendations were stated in the RAE 2012:

”In some of the divisions, there is insufficient willingness to take structured, coordinated steps towards increasing the research budgets. Whilst there was a commitment to supporting individual researchers and collaborative research projects, the UoA needs to develop a clear vision for the future and a clear strategy for its achievement. To strengthen its international profile, the UoA should consider recruiting international researchers to support both the newer research areas as well as to strengthen the better-established expertise.”

The Department has since 2012, and in particular, in recent years, worked with structuring and coordinating the research budgets. Divisions have been added to the department, and collaboration between the divisions has increased. Divisions with a large amount of teaching have received more of both internal and external research funding. More staff have been recruited in recent years, and further recruitments are planned for the coming year. Recent years have been spent on operative questions to a large degree, with a reorganization, moving to new facilities, as well as restructuring the faculty due to a large number of retirements, etc., but now the focus is on developing visions for the future, both within the divisions and for the department as a whole, as well as strategies for how they should be achieved, with staff recruitment, discussions on research focus, etc. In recent years, recruitment of international researchers has been made in several of the divisions, and more international Ph.D. students and guest researchers have been added to the department. Recruitment processes have become more open in accordance with KTH principles, with larger possibilities for international researchers to apply, and in general, the number of new positions has increased. Research collaboration with international partners has also increased in projects and publications.

3. Viability

The department has a yearly revenue of approx. 80 million SEK with about 50% from different kinds of research funding.

Real Estate Planning and Land Law

Within the field of real estate planning and land law, there are contextual limitations of the possibilities to obtain external funding. The reasons for this are several. For trade and industry, the findings and results from research in the field are rarely commercially exploitable. The division's targets, in terms of public authorities and organizations, do not have a government mandate to use resources for funding research in the domain at hand. For research councils and similar, the research field does not belong to the "hot spots". This results in that the research projects undertaken to a large degree have to rely on internal funding (or no funding at all). However, there are exceptions, and we could, for example, mention a funding initiative from the industry that has focused on housing (16 MSEK, Bostad 2.0), where a few projects deal with planning and land law. The cooperation with the Swedish Land Registry on industry doctoral students is another example of research funding typical for the subject area.

Real Estate Economics, Finance, and Business studies

Most of the external research grants are obtained from applied and industry-relevant research funding organizations. Developments are that funding directly from industry becomes a bit more scarce, and that greater reliance is put on research foundations and applied government research initiatives. This

development is in line with the fact that industry becomes leaner and that industry does less Research and Development. The industry expects that the Swedish state funds research.

Among external funders of research in the requested period are governmental funding agencies: Formas, Vinnova, and Swedish Energy Agency (Energimyndigheten). Some examples of different funding actors from the real estate industry sector are Veidekke, Stockholms Studentbostäder, Skanska, NCC, Bostadsbolaget, and Lundbergsstiftelserna. A recent industry funding initiative, involving more than 20 actors from the sector, has focused on housing (16 MSEK, Bostad 2.0), where most projects are dealing with real estate economics, finance, and business studies. And among funding actors of research on finance and financial systems are all larger actors within the Swedish financial industry: Swedbank, SparbanksAkademin, Handelsbanken, SEB, Nordea, Länsförsäkringar and the union Finansförbundet.

Construction and Facilities Management

The external funders of research in construction management are SBUF (construction industry research and development fund), Centre for Management in the Built Environment, Chalmers (including industry partnering organizations), The Swedish Transport Administration, Formas, Centre for Building Efficiency (including industry partnering organizations), and The Swedish Construction Federation. Government funding to the built environment has increased, both due to awareness of the high impact of this sector on sustainability and to intense lobbying and commitment by a united industry initiative (IQ Samhällsbyggnad).

Important external funding sources for studies in real estate management are Smart Built Environment/Formas, ProcSIBE/Formas, SIRen/Formas, Swedish Energy Agency (Energimyndigheten), Kamprad Stiftelse, Grön BoStad Stockholm/ERDF European Regional Development Fund, the Swedish Transport Administration and Mistra. There is also direct funding from housing companies and municipalities.

A professorship in real estate management (2016) is funded by a total of 10 MSEK by a group (20) of real estate owners. This funding is available until 2023. A similar funding initiative has focused on housing (16 MSEK, Bostad 2.0), where a few projects dealt with real estate management. Internal start funding from KTH of 3 MSEK has been provided for the professorship.

Geodesy and Satellite Positioning

Generally, it is considered difficult to obtain funding for research in geodesy, because the topic falls in between the field of natural science and the field of technical sciences. This means that there are relatively few organizations from where it is possible to apply for funding for research in geodesy. This has been and still is a major challenge for research in geodesy. However, it forces geodetic researchers to think “out of the box” to obtain research funding, and during recent years the division has been

successful in obtaining funding for projects in fields which are perhaps not classical geodetic fields of research.

The Geodesy Division has been the project leader for many Erasmus projects. Although Erasmus funding focuses on education and research capacity building, it also provides opportunities for research cooperation.

In addition, the division has also been involved in some research projects spanning from physical geodesy, Earth's geodynamics to deformation monitoring of man-made structures with geodetic methods, and 3D digitization such as: Studying Moho Topography and Its Density Contrast by GOCE, (2011-2013), a research project that is supported by Swedish National Space Board (Rymdstyrelsen), Project no. 76/10:1; Modelling the Earth's crust by combining GOCE, terrestrial gravity and seismic data (2013-2016), a research project that is supported by Swedish National Space Board (Rymdstyrelsen); Deformation network design of man-made constructions, (2013-2015), a research project that was supported by FORMAS; Climate change detection by taking advantage of a future satellite mission: GRACE Follow-On supported by KTH space center (2017); "Stomnät i luften" supported by Swedish Transport Administration (Trafikverket) (2019-2022); Development of geodetic surveying techniques for archeological studies in the Arctic, funded by the Tryggve Rubin Foundation (2017); "Industrial thinking through the full value chain in coupling geodesy, geodata quality, and BIM" funded by the Swedish Transport Administration (Trafikverket) (2017 – 2020); "Data quality and data responsibility in the built environment" funded by the Smart Built Environment program and FORMAS (2017-2019).

Academic culture

It is difficult to see how the department could be internationally competitive in the separate academic disciplines, based on the limited resources and few faculty that the department has at its disposal. However, the department is a dominant force in applied research in the Nordic countries and does leading research that takes advantage of the strong ties that the department has with industry.

The academic culture has been developing since RAE 2012 with a strong and systematic focus on research, publications, and funding, as well as a more elaborate focus on replacing retiring colleagues by recruiting in international competition. Changing staff also makes culture change, and an earlier focus on reports and production published in Swedish is replaced by publishing in international peer-reviewed journals.

We currently have a seminar series (Thursday lunch every week) with broader research content and a series of seminars on qualitative methodology and management studies, and a planned seminar series on research on Real Estate Finance. We have a joint working paper series. Our program director for the doctoral program in RECM annually organizes a quality meeting with all the main supervisors, where

the quality of dissertations is discussed. At these meetings, there is also a discussion about how the environment can be improved in its entirety.

Many research projects are carried out as temporary and externally funded PhD-projects involving a team consisting of a PhD-student, a main supervisor, and at least one co-supervisor. The aim is that supervisors shall complement each other in terms of experience, research focus, network, and gender. To handle this, co-supervisors from other universities and other disciplines are invited to join the projects. Positive effects of the collaborations and invited researchers have increased research networks, benchmark possibilities, and improved research funding and publication output.

The department has established relations to, and active participation in, strong international research communities in all of its disciplinary areas. Examples are:

- In planning and land law, for example, a Nordic network for collaboration in research and research education, and the European Academy of Land Use and Development (EALD), which is an association for regularly scientific meetings in the form of symposia, peer-reviewed scientific works and establishment of international research cooperation.
- In real estate economics, finance and business studies, for example, European Real Estate Society (ERES), American Real Estate Society (ARES), Pacific Rim Real Estate Society (PRRES), European Regional Science Association (ERSA), Western Regional Science Association (WRSA), The European Network for Housing Research (ENHR), Gender, Work and Organization (GWO), European Group of Organizational Studies (EGOS), Process Organization Studies (PROS).
- In construction and facilities management, for example, International Research Network on Projects (IRNOP) and Making Projects Critical (MPC), European Group of Organizational Studies (EGOS) and European Academy of Management (ERUAM), Industrial Marketing and Purchasing (IMP) and ENRIC, and Association of Researchers in Construction Management (ARCOM). There is also a working Commission in CIB on Facilities Management and Maintenance (W070), which meets in conjunction with general CIB conferences (always at the World Building Congress).
- In geodesy, for example, the International Association of Geodesy (IAG), International Union of Geodesy and Geophysics (IUGG), European Geoscience Society (EGS), and Nordic Geodetic Commission (NKG).

Current faculty situation

In 2019, the Department had 64 full-time employees of different titles. The department also hosts three full professors (one man and two women) as guest professors and one full professor as an adjunct

professor (a man financed from the industry). They contribute to research as well as in teaching and are an important part of the senior intellectual capacity of the department.

Out of the associate professors, three men and one woman (4 persons) will have retired in a five-year period along with one lecturer (woman).

The department has a balanced gender distribution among employees, as well as among PhD-students and undergraduate students. However, as we see in the table above, the distribution between men and women in the higher ranks (full professors and associate professors) is skewed. With a higher proportion of men than women in the faculty group, replacing those soon retiring could provide a chance for more balanced gender distribution. However, when recruiting, the best candidate is selected, regardless of gender, so the upcoming distribution may remain skewed within the faculty group. The guest professors are a strategic way of handlings this situation so that the culture can stay mixed.

If, on the other hand, we broaden the perspective intersectionally and also include ethnicity, we find that the group with employment as a researcher or with any other title not included in what is defined as faculty, consists entirely of women and men with an international background. All full professors and associate professors except one were born in Sweden. This aspect should, therefore, be highlighted as it signals that the recruitment strategy of the department has not been in line with KTH objectives.

Recruitment strategies

For the following five-year period, the main strategic focus is on balancing the staff with regard to the amount of personnel for teaching and research. The department has still not fully handled the big group of faculty retiring, indicating that an important task is the systematic recruitment of skilled faculty in international competition. Another important strategic choice is to restructure the staff according to the general idea of how to organize this in a university. Due to the scarcity of faculty (as a direct effect of retirements during the recent years) in relation to the departments' teaching assignment, a large number of researchers are presently working with teaching and faculty services. As the possible effect of this might be that the research output is negatively affected, more traditional staffing is to be aimed for, where faculty members bear the main responsibility for the development of the subject areas, and researchers are project funded in the same way as post-docs and doctoral students. To reach this balance, recruiting is necessary.

The main research infrastructure consists of different databases and a number of geodetic instruments mostly used in teaching but also for research purposes. The Department had – until 2018 – a local BIM-lab (Building Information Model), but this was shut down as the School of Architecture, and Built Environment supported the development of a new joint Digital Lab available for all KTH. The

Department of Real Estate and Construction Management will, from now on, use this resource for teaching and research.

4. Strategies and organization

All research environments within the department are presently committed to producing more and better research. We have a clear objective to increase the number of publications each year. We start at the department level by focusing on more publications/citations and will, in the coming year, also focus on higher-ranked journals. However, within some of our research groups, we have already progressed further, and focus will instead be on improvement and excellence.

However, the opportunities to produce more publications in the short term are entirely dependent on opportunities to recruit to strengthen teaching. At the department level, the priority in the short run is to include the entire base of research staff on a shift towards more publications. Our history and tradition show strength in education and impact, so we will, of course, continue to also work with these important university tasks. The main strategy for change in our department is to balance the proportion of published research and, at the same time, maintain quality in teaching and time for collaboration with the surrounding community. We will also strive for increased co-publishing of various kinds and a higher degree of open access publishing.

In the short run (1-3 years), a rising trend in publications is thus expected. In a longer perspective, a progressively higher citation rate increased co-publication, and publications in "better" journals are expected where possible. We have good hope of succeeding well with this, as the necessary new recruitment mentioned elsewhere are planned to take place in a 1-3 year perspective.

KTH Development Plan 2018-23 indicates the overall goals for the university, and these objectives are specified in the ABE-school development plan. The goals defined at the department level are compatible with a general university-level goal of excellence in research, education, and industry collaboration, as the department is good at achieving all three of these objectives. Research is done as an integral part of education and industry collaboration. The department is striving for the development of all three activity-dimensions. However, the development of stronger research culture is prioritized in line with the goal of a leading KTH.

The Department can, in itself, be regarded as an example of the strategy of integration, as it hosts different research traditions and fields of study with a common applied interest in real estate and construction management. The KTH goal of higher visibility of research and other activities could

inspire the department to further develop, and the aim is for this to be made easier in a five-year period when new recruitments have replaced colleagues that have retired.

Open, digitalized, sustainable, international are all keywords that are an integral part of our development plan at a department level. They inspire the daily work and are reasons for structured revisions of the yearly output at, for example, the department conference.

The KTH/ABE-goal of equal opportunities is in special focus of attention of recruitment of new faculty due to the defined present need to change in-balances in the distribution of gender and ethnicity among department staff.

The leadership structure is traditional flat Scandinavian collegial leadership. The Head of Department leads the department, and there is also a Deputy Head of Department. A Head of Division leads each division. All these leaders (7 persons in all) compose the Heads Group, which has frequent meetings. There is also a larger Department Management Group, in addition consisting of education Programme Directors, Director of Studies, HR representative, Economic department representative, Head of Administrative group, and doctoral student representative, which meets a few times per year. There is also a Council of Professors and a Research Education Board.

The quality work is done by publication of good research in high-ranking international research journals. All Ph.D. theses are reviewed prior to publishing, and most of them write compilation dissertations, which consist of scientific papers published in or submitted to scientific refereed journals. A large part of the research projects relies on external funding, which is won in competition and thus a quality recognition of both the previous research and the outline of the applied research project. All recruitment in the department is done in competition.

5. Interaction between research and teaching

Most of the staff from the department are active in both teaching and research. In addition, staff employed as researchers participate to a large extent in teaching. The staff teaches in courses given by the department and outside of the department, as well as research within the subjects that they teach in, which means that research and teaching are closely connected. Teaching is done in courses at all levels, BSc, MSc, and Ph.D. level, as well as in commissioned courses for people already working in the field. Knowledge and results from the research are included in the contents of the courses and used as examples and cases in the teaching. The level of research-connected teaching increases in the courses

on the advanced level and courses at the MSc level is intended to prepare students for research. Research articles and papers, both by the department staff and by other national and international researchers, are used as course literature. Especially in the Theory of Science and Research Methods course and in the master's degree project, students are trained in research preparation activities, such as literature search, method selection, analysis, and scientific writing. The degree projects are sometimes connected to research projects in the department. Staff lead teaching in Ph.D. courses, as well as supervision of PhD students, from the department. Ph.D. students carry out a lot of the research at the department.

For the RICS accreditation of the MSc program in real estate and construction management, it is also important that the teaching is closely connected to the research. It is possible to apply for funding for research from the accrediting organization within the program subjects, which are closely connected to the subjects of the department's research.

One of the strengths of the department is that former students populate most of the leading positions in the industry, and also that doors to the industry are usually open. At the BSc level, the industry is invited to give guest lectures and to discuss the relevance of the curriculum for the competence that the industry wants in students. BSc project courses are designed in collaboration with industry to ensure that teaching is relevant and that they also focus on research areas. For instance, a recent course covered sustainability reporting in real estate, which is also a research project, and which is of interest to industry. Ph.D. students are supervised in teams that include industry partners, and there are quite a few industry Ph.D. students.

6. Impact and engagement in society

Social relevance in our research is essential. The department is largely engaged in applied research and has a great deal of dependence on external financiers, mainly from the industry. The importance of relevance is, therefore, crucial. The research is carried out with external funding obtained in competition with other applicants and where relevance to society is usually an evaluation-criteria for selecting projects for funding. The teaching and the research connected to the teaching at the department directly affect the future alumni that will work in practice. The research areas, such as real estate, finance, and land management, are central societal functions. Many of the employees in the department hold positions with institutions in society, such as funds, committees, and they also produce many reports to the government on industry matters. It is also common for the department staff to be present in the media.

The research is, to a large extent, primarily problem-driven and directed towards public and private actors, such as real estate owners and service providers, and indirectly also to users. Results are also relevant for municipalities and the national policy level. Land development and land management

encompass many different actors and competencies during the various stages, from planning, projection, and building/constructing to managing the built environment and the infrastructure. In addition, major stakeholders for the department's applied research are the industry networks, such as The Swedish Construction Federation (Byggföretagen) and the network of Swedish Construction Clients (Byggherrarna). Several of the research reports and articles produced by the department have resulted in legal reforms, with a direct impact on society.

As examples of relevance to society can also be mentioned that the department is by large the main producer of textbooks for educational purposes on a national basis in the area of Real Estate Planning and Land Law. Textbooks and other materials are used by most other Swedish universities offering educational programs in this field.

Some key external stakeholders that are in focus are public clients of urban development and infrastructure, such as The Swedish Transport Administration and Stockholm municipality, as well as private and public client/owner organizations. Clients, through their position as an initiator of projects in the built environment sector, have the power to demand and drive industry change through their procurement strategies and requirements. In addition, engineering and management consultancy firms in project management and construction project management benefit from investigations of current strategies and practices, which can serve as suggestions for improvements and innovations.

The extensive research on physical geodesy and geoid modeling is applied by many national mapping agencies for developing geoid models, which are crucial for the height component in high accuracy positioning and navigation with GNSS. During the reporting period, the department has had close cooperation with several government organizations in Sweden. The department has ongoing research cooperation with Lantmäteriet around physical geodesy and improved GNSS positioning, and with the Swedish Maritime Administration (Sjöfartsverket) on high accuracy GNSS positioning.

An important channel for dissemination of research results is through the examination of MSc and Ph.D. students, as well as through adjunct professors, guest professors, also working in companies, and industrial Ph.D. students. Some faculty members combine KTH employment with sideline jobs. Both faculty and Ph.D. students participate in national and international conferences and write popular science papers, participate in industry and society conferences and forums, as well as participate in media (radio, television, magazines, public panels and seminars, industry media and social media such as blogs (Samhällsbyggarbloggen) and pods (Hela Kedjan)), international committee work, develop handbooks and responses to governmental investigations and proposals. Research is also disseminated through networking, such as the Centre for Construction Efficiency. Other forums where the department is active are industry professional's networks, co-creative arenas, boards and councils, and reference groups

where clients/developers, contractors, real estate owners, etc. share knowledge, develop guidelines and make the policy impact. There is also joint research together with actors outside academia, such as the municipal housing company Helsingborgshem, resulting in a new, and inclusive rental policy. There is participation in reviewing and writing new technical guidelines, e.g., HMK - Handbook of surveying and mapping issues published by Lantmäteriet.

Research is presented at industry events such as Samhällsbyggnadsdagarna, Centre for Management in the Built Environment, Årets Bygge, Business Arena, and events at Almedalen political event. Smaller meetings/seminars with research partners and sponsors are also organized. Other forums are the Strategic Advisory Board of the funding agency E2B2 (part of Swedish Energy Agency), advisory groups of Förvaltarforum (REM website), AFF (standard contract owner org), Swedish Royal Academy of Engineering Sciences, and other conferences organized by the Swedish branch organizations (Kartdagarna, Geodesidagar).

A significant contribution has been how to measure price dynamics in the owner-occupied property market. Several articles on price index construction have resulted in what is today considered the official housing price index in Sweden, namely the HOX index that has been constructed at KTH, is produced by the company Valueguard AB and distributed by the company NasdaqOMX.

An important research output directed to society is that the department is consulted for Government referrals regarding feedback and suggestions on legislative proposals within the research field at several instances every year. For some legal reforms, researchers from the department have been involved as experts, academic investigators, and secretaries. Several of the research reports and articles produced by the department have resulted in legal reforms.

The research in project communication and construction project management, including project-based organizing, provide impact for industry and society in terms of, for example, investigations and international benchmark into best practices, the development of standards in relation to, for example, BIM and Collaborative business relationships, guidelines on procurement strategies and requirements, and key methods for driving innovation, change and sustainability in the built environment sector. Policy papers have been developed primarily regarding procurement for carbon reduction in the Impres/Mistra Carbon Exit project.

As other examples of research dissemination beyond academia can be mentioned a professorship in real estate management funded by a group of real estate owners, and a similar funding initiative focused on housing (Bostad 2.0), where the research areas have been developed together with the funding partners from the industry and organizations, the partners are active in reference groups, and seminars are held to present the results to the funders and other interested partners, as well as producing research and popular science publications.

Several of the sustainable development goals are dealt with in the research of the department and its publications. According to the bibliometrics, the goals that are present in the highest number of publications are SDG 13, 11, 14, and 9, i.e., Climate action, Sustainable cities and communities, Life below water, and Industry, innovation, and infrastructure.

It is estimated that 40-60% of the department's research is related to sustainable development, or somewhat higher in some of the research groups. Sustainability issues are present in much of the research conducted primarily in housing economics, but also on office markets. These include affordability, sustainable cities and communities, and climate actions. Research on segregation and the economic performance of "green" office buildings are examples of research with a sustainability focus. A clear and entrusted system for ownership and property rights connected to defined and legally protected territories and parcels of land is of fundamental importance to a number of the United Nations' Sustainable Development Goals. This is relevant, both in terms of creating security and long-term stability for ongoing land uses, but also in order to enable and facilitate changes when the need arises to employ the land in another way or to protect it and preserve some land uses against inappropriate deteriorations. Real estate and finance are of great importance for societal development. One such project focuses on green bonds for sustainable real estate. Another project focuses on how bank branches foster entrepreneurial business growth. Yet another project focuses on the financial inclusion of the young, and there is also research on equality.

Some examples of the contribution to meet other goals can also be mentioned. SDG 2 Zero hunger is related to research in developing countries, where land conflicts over ownership and other property rights are frequent. Real estate planning and land law deal with issues of land titling and registration, land consolidation.

SDG5 Gender equality is related to women's access to land, which is often an obstacle in developing countries. In real estate planning and land law, two doctoral thesis projects concern this topic.

Several research projects have been dealing with SDG 9 and the responsibility and financing of infrastructure. A current international project concerns the issue of public value capture. Several projects have studied problems and solutions regarding informal settlements and slums in developing countries related to SDG 11.

Regarding access to safe and affordable housing, several projects have been completed, and a number is currently ongoing.

An example within construction management studies on negotiations on sustainability requirements and horizontal collaboration for innovation in urban development in collaboration with Stockholm

municipality and private housing developers (SDG 7, 9, 11, 12 and 13), from the national procurement program ProcSIBE (SDG 9 and 11), and by the longitudinal studies on horizontal integration and collaboration for innovation in urban development (SDG 9, 11, 12 and 13). Several goals are addressed in facilities management as well, e.g., energy, Green Building, indoor climate, digitalization, knowledge transfer from use to construction, innovation management (SDG 3, 7, 12), social sustainability in disadvantaged areas, innovation management, digitalization (SDG 10, 11), as well as digitalization, innovation management, maintenance, and outsourcing strategies (SDG 9).

A large part of the research carried out in geodesy is related to the monitoring of climate change, which is an important part of the SDG 13. When glaciers are reduced or diminished, one of the effects is that the landmasses rise as they are freed from the weight of the ice. This land uplift can be estimated, and modeling by gravimetric methods and gravimetric land uplift models developed at the department contributes to a better understanding of the consequences of climate change to the Earth's surface. Further, such land uplift models are important in estimating sea-level change, which is another consequence of climate change caused by both increasing water temperature and melting ice from the large glaciers in the Arctic and Antarctica.

In addition, the research carried out within the fields of GNSS, Geodata quality and geodetic aspects of BIM is relevant to the SDG in terms of contributions to, e.g., sustainable agriculture (SDG 2), sustainable economic growth (SDG 8), more resilient infrastructure (SDG 9) and sustainable cities and communities (SDG 11). Work on improved methods for GNSS positioning and navigation when applied to machine guidance and autonomous machinery in farming contributes to the concepts of "precision farming" and "smart farming", which are both concepts for obtaining more sustainable agriculture with a reduced need for e.g., fertilizer and watering of agricultural fields. The same methods of improved GNSS positioning and navigation lead to more resilient transport infrastructure with autonomous vehicles and trucks and more efficient traffic flow, which in turn reduces the need for fuel, electricity, or other propellants for vehicles.

Research on geodata quality and geodetic aspects of BIM contributes to more efficient processes in the built environment from planning through construction and maintenance of infrastructure, buildings, etc. This, in turn, contributes to sustainable economic growth, more efficient use of resources in building and construction, and it contributes to more sustainable cities and communities.

Since sustainable development has been integrated into the research base for a long time in the research of the department, it has not increased so much since 2015. However, it has been applied to new areas, such as innovation management, business networks, and knowledge integration in the early stages of the construction process have important implications for sustainability. The department has initiated national and international collaborations specifically focused on sustainability, e.g., ProcSIBE, Centre for building efficiency, and Impres. Other new themes since 2015 with important implications for

sustainability are digitalization, innovation management, and knowledge transfer from use to construction. The integration of sustainable development since 2015 has also been driven by an increased focus from the organizations that fund the research, which directly affects applications made for external funding. Also, increased awareness among faculty on how the research can contribute to sustainable development has increased the integration of the SDG.

The Department of Real Estate and Construction Management is constantly engaged in a number of applied research projects with direct and indirect impact on the industry, policymaking institutions as well as NGO:s and the society at large. For the purpose of RAE 2020, we have selected two impact cases of a different character: Digitalization in the land surveying field; and The ProcSIBE national strong research environment.

CASE 1: Digitalization in the land surveying field

The digitalization of the public sector and public administration is a highly prioritized concern in Sweden, as in other countries. The Swedish Government has launched several programs involving digitalization of different elements of the land development process, digital land-use plans, creation of a unified national geodata infrastructure, etc. The Swedish mapping, cadastral and land registration authority (Lantmäteriet) is the national coordinator for the digitization of the planning and building process. Research at the Department of Real Estate and Construction Management (RECM) in the land-surveying field has been contributing to several phases of this process.

Phases from the idea to decide on the detailed plan. The process starts with an idea inspired by the needs and the current status of actors within the built environment (both physical and legal). The idea is then developed into a comprehensive plan and a detailed plan. The current state is recorded in the databases based on the up-to-date geodata, which is maintained by the municipalities and Swedish mapping, cadastral and land registration authority. Several research projects at RECM have been related to refinement and development of data collections methods for geodata - as well as the quality assurance of the new data collection methods, which are nowadays routinely used for fast updating of the geographical databases. In many building projects, it is very important to assess the geological stability of the area and to detect possible tectonic motions. The Department has performed research in this area – using GNSS for monitoring of slow motions and has an on-going project where interferometric synthetic aperture radar and satellite gravimetry is used to detect small motions over large geographic areas.

The research at RECM also approaches the pursuit towards digitalization from a legal perspective, since a fully digitalized planning and building process requires comprehensive and explorative analyses of the legal domain of real property law. Typical questions to clarify includes:

- Are there impediments or restraints in the structure and internal relations of the legal system? Decision-making systems must reasonably reflect the logic on which the legislation is based.
- How can digital technology handle legal provisions requiring qualitative assessments, where the underlying criteria are neither quantifiable nor well defined?
- Can the ICT be designed to make trade-offs between public and private interests, or between conflicting private interests?

Design phase. In the next phase, after the detailed plan is approved, the projections of the constructions and property formation can commence. Both steps require reliable and up-to-date base documents containing the geometric and legal status of the concerned properties. Even today, this information is not always available in digital and searchable form. The department, together with Lantmäteriet, performed a study on methods of digitization of older maps and documents. It was shown that the availability of the base documents in digital form could shorten the process of property formation by several months.

However, on the legal side, one important study identified several complex and unclear interdependencies between property formation and land use regulations, which may create obstructing impediments to digitalization and automation of the property formation process. The specific legal connections between property formation and land use regulations were also analyzed and evaluated in a doctoral thesis, which resulted in a recommendation for major legal reform, in order to facilitate the technological transformation to a digital property formation process.

In a succeeding comparison of the legal provisions for property formation in Finland and Sweden, it was found that the Finnish legislation does not contain the same type of interdependencies between property formation and land use regulation present in the Swedish system. At the interface between legal and technical issues, the article also noted that a legal reform where property boundaries primarily are defined by coordinates will to a large extent, facilitate the utilization of the potentials with digitalization. However, both in Finland and Sweden, the quality of the boundary coordinates in the digital register map must be improved in rural areas, in order to reflect the true location of boundaries. The obstacles and possibilities for using 3D digital models, such as building information models (BIM) and 3D geographic information systems (GIS) have also been studied.

On the technical side, even the projections of the constructions benefit from the availability of base documents in a digital and standard form. The research deals with the standardization of the format and integration of geographic and cadaster data coming from different sources. When integrating data from different sources, it is of utmost importance to use a common and well-defined reference system; this issue was studied, where one of the most important findings was that the current standard for BIM does not fully support strict conversion between reference systems. This research also proposed a method for

automatic object extraction from 2D images and 3D point clouds in order to create precise and detailed geometrical 3D models, which are necessary as a base for the projection.

Regarding involvement in the necessary legal reforms, RECM has, over the last years, also been consulted for several Government referrals regarding feedback and suggestions on legislative proposals within the field of digitalization.

Construction phase. A pre-requisite for the correct geometric realization of projected construction is a geodetic reference system. The Swedish mapping, cadastral, and land registration authority are responsible for its definition and realization on the national level. The research conducted in the area of precise geoid determination resulted in a theoretical foundation, known as the KTH method, which is today used by the Swedish mapping, cadastral and land registration authority and in several other countries to compute and maintain national geoid models. RECM participated in the research project "Control network in the air" conducted in cooperation with Trafikverket, which resulted in a more effective method for the realization of the national reference system on the project level. The approach developed in this project has been applied to several large infrastructure construction projects. A new research project with the goal to refine and further develop this realization was started in 2019, and RECM is one of the leading participants.

CASE 2: Infrastructure construction procurement: ProcSIBE and the Swedish Transport Administration

The ProcSIBE national strong research environment. ProcSIBE, Procurement for Sustainable Innovation in the Built Environment, is a national research platform to support the development of new knowledge within the field of procurement of buildings, infrastructure, and building-related services. The platform was initiated in 2014, following from a call by the Swedish Research Council Formas for Strong Research Environments to address important challenges related to the built environment. ProcSIBE involves research groups focusing on construction procurement at KTH in Stockholm, the Chalmers University of Technology in Göteborg, Lund University, and the Luleå University of Technology, as well as the Department of Political Science at Karlstad University. The basic funding from Formas amounted to a total of 25 MSEK over 5 years, but the researchers have since acquired more than 50 MSEK of additional funding from other public and private bodies. Numerous PhD-projects have been started, and extensive collaboration with the Netherlands has been established based on a Formas guest researcher grant. This expansion also allows for the collaborative platform to continue over several more years.

This impact case focuses on the collaboration between ProcSIBE and the Swedish Transport Administration (STA) within infrastructure procurement, which represents a large part of the total volume of the ProcSIBE research. It should be noted that a parallel ProcSIBE program in the building sector relates to a long-term strategic collaboration between KTH and Stockholm municipality in the

Stockholm Royal Seaport area. This program involves several Ph.D. students and is co-funded by Formas and the Centre for Construction Efficiency.

Importance of construction procurement for sustainability and innovation. Many major challenges that today's societies face, from climate change to an aging population, are intimately linked to buildings and built infrastructure. The application for the ProcSIBE platform was based on the awareness of the central role that construction clients play in driving innovation and change in this project-based sector. Most design and construction tasks, including many planning and maintenance activities, are procured from private sector firms. This means that clients' procurement strategies and requirements strongly influence supplier firms' investments in new practices, competencies, and technologies. Inadequate procurement strategies may result in delays, costly lawsuits, poor use of knowledge, lack of efficiency and innovation, quality deficiencies, and poor safety performance. Still, traditional price-focused procurement strategies are often used even when project goals and circumstances call for more flexible, integrated, and innovation-oriented approaches.

Procurement in this sector is complex and based on expertise within several fields: purchasing, public procurement, construction law, and project management. Still, structures for learning and industry-academia collaboration in the field of construction procurement have traditionally been weak in Sweden and research efforts comparatively limited. An important aim of the ProcSIBE collaboration has been to coordinate and integrate the activities of several research environments to establish a strong national transdisciplinary research platform with higher potential for gaining impact in industry and society. The collaboration with the Swedish Transport Administration represents a case of long-term capacity building for joint learning in this field.

The ProcSIBE collaboration with the Swedish Transport Administration. The ProcSIBE collaboration with the Swedish Transport Administration (STA) started around 2014 with a few small, ad hoc studies and has subsequently developed into a research program that today encompasses more than ten substantial and coordinated projects.

The STA was established in 2010 as a merger between the former road and rail administrations. The previous regional structures were then re-configured, and a central procurement unit was set up. The collaboration with ProcSIBE was initiated by the then acting Purchasing Director, who began to build knowledge and new practices in this field. Key input around purchasing, in general, was sought from private sector companies, but for knowledge of construction procurement, a report issued by the Swedish Competition Agency was an important starting point. This report was developed by one ProcSIBE researcher in collaboration with a construction lawyer. Around 2015, the STA relied heavily on a so-called "pure client" procurement policy, focusing on shifting responsibility to the supplier side by increasing the share of design-build contracts for contractors and fixed-price contracts for engineering consultants. The report, by contrast, suggested that procurement models should be adapted to the needs

of the project, meaning that a wider range of contract forms, including traditional contracts and collaborative contracts, should be considered. One researcher was engaged by STA to help them establish new guidelines for the selection of procurement strategies based on these ideas.

In 2016, a successful application to another Formas call, co-funded by the STA and based in ProcSIBE, was led by a researcher from the department. The internal application process within STA was handled by a Procurement Strategist with a Ph.D. degree from the Luleå University of Technology, now responsible for innovation and research within Purchasing and Logistics. This resulted in a new large research program, initially comprising three Ph.D. projects and one post-doc project. Two complementary Ph.D. projects were added in 2018-2019, and several smaller research projects involving senior researchers have also been carried out. STA has established a communication structure to handle the ProcSIBE projects, and over time, a number of other procurement-related research projects have been associated with this platform. Thereby, ProcSIBE acts as an integrative hub for most STA research in this field. Since the start, altogether eight Ph.D. students and one post-doc have been involved in the wider ProcSIBE-STA collaboration.

Most of the core ProcSIBE projects focus on following up and evaluating STAs procurement practices, for both contractors and consultants. The main areas are Design-Build contracts (also with maintenance responsibility), collaborative contracting strategies (Early Contractor Involvement), social value in procurement, consultancy procurement, procurement of maintenance services, innovation-oriented procurement, and STA's system for following up supplier performance. Associated projects focus on, for example, the project manager role, procurement requirements for carbon reduction, and, most recently, on purchasing category management.

Impact summary. Most projects within ProcSIBE are still ongoing, but many have already provided intermediary data about how procurement strategies have affected project processes and results. This input has raised general awareness within STA and is regularly considered in their further strategy developments, which have generally been in line with the research-based recommendations. However, the impact of research is not only related to the direct implementation of new practices in projects but also to the establishment of new organizational processes, resources, and structures. Below, we summarize the research impact so far:

- The collaboration has strong support from the STA Purchasing Director (both the former/initiator and the current), and the results from ProcSIBE projects are presented each year to an STA top management group (Beställarrådet).
- The STA Business Strategy/procurement strategy has been updated several times with continuous input from ProcSIBE (currently the version 3.0 is in place). Starting in 2015, Per Erik Eriksson has been affiliated with the STA workgroup that is responsible for developing the procurement strategy.

- The size of the program motivated a committee at the Transport Administration to handle the portfolio, aside from the individuals who are responsible for each project. This committee is led by the Procurement Strategist with a Ph.D. degree.
- A result seminar is held in October each year, where results from all ongoing projects are presented to STA representatives from the Purchasing and Logistics department as well as the business areas and the strategic development unit. Thus, it has become an important forum for cross-departmental communication around procurement within STA.
- Researchers from the department were affiliated to the External Advisory Committee, supporting the former STA Purchasing Director.
- In line with recommendations from ProcSIBE, a dedicated organizational function to strengthen STA capabilities within collaborative contracting is currently being set up within STA. One of the department researchers has further participated in several tender evaluation committees for collaborative (ECI) projects within STA. She is also a member of the Swedish Committee for the ISO 44001 for Collaborative Businesses Relationships Management, in which the STA and all large infrastructure contractors also take part.
- An associated ProcSIBE project has studied the implementation of procurement requirements for carbon reduction worldwide, including Sweden. The project was co-funded by Construction Climate Challenge (Volvo CE) and Mistra Carbon Exit, and carried out in collaboration with WSP and Skanska. It has resulted in concrete recommendations for updating the STA model as well as policy input to the Swedish Climate Policy Council and EU bodies.
- Ph.D. students are important boundary spanners between academia and industry. Two ProcSIBE Ph.D. candidates are industrial PhDs employed by the STA. This facilitates direct information and contacts in both directions and, thereby, the implementation of research results.

The department, with its five divisions within respectively different research fields, is recently (in 2019) restructured to gain the possible output from multidisciplinary collaborations in different forms. With a solid focus on the built environment, the combination of research within the disciplines of geodesy, planning and land law, economics, business studies, and management gives vast possibilities for solving problems defined together with other parties in society. At a department level, structured joint activities are arranged to give every employee a better overall picture of the differences and commonalities of different disciplines and research approaches. A common interest in developing skills in methods is also promoting cooperation. The long-term strategic goal of these activities is to form better multidisciplinary teams for applications of research funding, as well as for solving applied research problems identified with actors engaged in promoting the built environment. This, of course, also involves different research

collaborations with colleagues at KTH and at other Swedish universities, as well as disciplinary and multidisciplinary international research networks.

Department of Sustainable Development, Environmental Science and Engineering (SEED)

1. Overall analysis and conclusion; Strength and development areas

Strengths

Research

- Type of research:

SEED's research is multi- and transdisciplinary, problem-oriented, impact-based, and mission-driven. It takes a systemic approach and, thanks to a diversity of competencies, covers many sustainability areas

- Communicating research:

SEED's research generates a lot of interest inside and outside academia and, through extensive cooperation with a diversity of partners, leads to high impact on society

- The department gets a lot of external funding

Organization

- Cooperation within the department

Informally well functioning. Good discussion climate. Centralized 1st and 2nd cycle education at SEED has led to a better use of teaching staff. The reorganization has taken some time, but now the decision structure has become clearer.

- Diversity

Reasonably gender-balanced in the department (but could be improved)

Weaknesses

Research

- Unclear description of topics we do research on

Is SEED's research known at KTH?

- Lacking competences

Need for more competences, e.g., on behavior issues, applied ecology, environmental assessments (SEA/EIA). Insufficient specializations? (a drawback of broad competences). Education needs competencies in "old" sciences, and research needs competence in "new" fields.

Organization

- Formal structures for cooperation within the department are lacking:

Could be more multi/transdisciplinary projects or discussions in the department. Lack of cooperation for application-writing

- Employment issues:

KTH Doctoral policy and due to current economic situation: very few doctoral students can be accepted => Lack of regrowth through new Ph.D. students as well as few faculty positions => difficulty in balancing teaching and research and some faculty overloaded.

- Insufficient Research basic funds (basmedel) to the department
- Economy and project management support are highly problematic

Difficult to plan ahead because of the lack of good economic support, especially in relation to the high overhead costs.

- Lack of consistency and clarity

Divisions do not mirror research areas 100%. Some people have strong research groups, and some do not. Low level of joint Ph.D. activities

2. Research profile

The Department of Sustainable Development, Environmental Science, and Engineering (SEED) was formed in 2013 to gather research on sustainability at KTH. This comprehensive organizational change took time, and the department is still working on creating a common SEED. In 2016, a topical review was conducted and in 2017, SEED was reorganized and then moved into a new building on KTH campus.

SEED conducts research and education focused on the sustainable development of society. SEED gathers a broad range of interdisciplinary expertise to conduct research that covers a wide field within environmental, engineering, and sustainability issues.

It consists of four divisions formed in 2017:

- Sustainability Assessment and Management
- Strategic Sustainability Studies
- Water and Environmental Engineering
- Resources, Energy, and Infrastructure

SEED also hosts the KTH Water Centre.

SEED has a large number of researchers (i.e., not part of faculty). One reason for this is that SEED's field of research is highly relevant for the sustainability transition of society and thus can attract research funding. In attracting funding, SEED competes with and cooperates with other universities and research institutes (e.g., IVL, SEI, RISE).

The research at SEED is mostly multi- or transdisciplinary due to the complex nature of the problems at stake and in order to cover all-important aspects to the research topics. A multi-disciplinary perspective is also key to the success and implementation of research results. SEED's research fields cover all the dimensions of sustainability, and SEED's aims are:

- to understand and support decisions that lead to the sustainable development of society by analyzing the effects of decisions from a social and environmental perspective
- to work in an interdisciplinary way and with stakeholder cooperation in order to influence social development
- to promote sustainable production and consumption practices
- to increase knowledge and improve the use of natural and socio-technical systems for managing water, land and other natural resources

The knowledge gaps addressed are many and cover everything from the need to develop new, improve, or challenge existing decision-making tools or approaches, participatory processes at different decision-making levels, how to tackle the gap between knowledge and action in many areas both from users (e.g. how more sustainable behaviors can be encouraged) and from public and private actors, all with the aim to alternative ways of living and organizing society as part of transformations to a low-impact society.

SEED conducts research that range from social sciences to natural sciences and on to engineering science. Therefore, methods ranging from in-depth qualitative interviews to quantitative analysis of measurements and large data sets are found at the department. The main research activities include the formulation of research applications, coordination of research, supervision of PhD students within research projects, master and bachelor theses, field studies, case studies, analyzing and synthesizing collected data into published, peer-reviewed, scientific papers, and presentation at scientific conferences. Research is most often done in transdisciplinary research projects, including co-creation

processes, and involves collaboration with other research groups or authorities and interactions with practitioners.

It varies among SEED researchers whether they belong to a research team within SEED or not. Some research teams are strong and well established, although informal, and are writing new grant applications together and collaborating on several projects. Other researchers, outside these informal groups, are either mostly collaborating with external researchers or with different colleagues at SEED depending on the specific project at stake. Thus, the divisions do not mirror research teams. Some researchers feel isolated, and SEED is investigating how research groups based on common methodological or thematical interests could be formed (the abovementioned four themes (Figure 1) is one example).

SEED's view is that gender is of importance in research topics, team composition, and collaboration with various stakeholders and that any working environment benefits from a multi-cultural gender-balanced structure. Wicked sustainability challenges of today require recognition of multiple knowledge spheres, where experiential and practical knowledge are treated as being as important as scientific/expert knowledge. Therefore, the inclusion of a wide diversity of knowledge is a key principle in the research team composition, where diversity is a source of creativity and innovation. Efforts are made in projects run at SEED to have gender balance in both projects and sometimes even work packages. Gender perspectives are very relevant for many projects when studying social practices, design of technology, and just transformations towards a more sustainable society where gender equality is one criterion for the social dimension of sustainability.

The number of peer-reviewed articles has been relatively constant, although it had slightly gone down in 2018. There is a greater variation in conference articles over the seven-year period with a declining trend. This could be due to a lower conference attendance or a lower tendency to include these types of publications in the DIVA system. As the table above has a low coverage in Web of Science (well below 60%), it should, therefore, be interpreted with extra caution. The volume of reports also varies over the period and may depend on which partners SEED collaborate within projects (the likelihood to publish reports when working together with public authorities, research institutes is usually higher). It could also depend on whether reports are systematically registered in Diva. Regarding the quality of research, almost 75% of SEEDs publications are peer-reviewed. When looking at the average citation rate for SEED between 2012 and 2016 over a 3-year period (publication year and the two following years), SEED's average citation is significantly higher for the period than the ABE School's average (5.2 compared to 3.3). Likewise, when looking at the period 2012-2017, SEED's publication impact and mean field normalized citation rate was 1.16, meaning that SEEDs publications are 16% more cited than the global average publications in the same WoS subject category. This is higher than the ABE average (which is only 5% more cited than the global average). SEED's share of the top 10 publications (i.e.,

belonging to the 10 percent most cited in its field) normalized for the WoS subject category, publication type, and publication year is 11, 4%, and therefore both above the world average and ABE average (both 10%).
When it comes to the choice of journals and their impact in terms of citations, SEED publishes in journals which are 20% more cited than the world average (ABE in comparison publishes in journals 14% more cited than the world average). Finally, SEED's share of publications in journals that are among the 20 percent most cited in their field is 27.8%, which is higher than ABE's share of 23.1%.

Based on the results of the bibliometric analysis, around 22% and 52% of SEED's articles and reviews registered in WoS for the period 2012-2018, were co-published with non-university partners and with international universities, respectively. This is above the average for the ABE school. SEED looks favorably on the mix of co-publishing. The co-publication with non-academic partners reflects, in SEED's view, a high degree of applied research.

In 2012, the SEED Department was organized differently in three distinct departments: Land and Water, Industrial Ecology, and Environmental Strategies research (as one division in the department of SoM). In the RAE 2012, it was concluded that these divisions/departments were doing good quality research and outreach, with high ambitions on impact and with a deep commitment to working with practitioners. They were partly assessed to be cohesive groups despite the diversity of research topics. Areas of improvement included to better integrate research across clusters, to recruit social scientists, and to increase collaboration within KTH. As a result of this, SEED was established. Up until now, all integration needed to make the most of the founding divisions/department has not been carried out and needs to continue and be supported by the school and KTH. In 2016, short, mid and long-term targets were set up with the establishment of the new joint department SEED. Most of the short-term targets have been reached, such as organizing internal seminars, updating the SEED website, or organizing an annual SEED day.

3. Viability

During the period 2014-2019, between 60 and 70% of SEED's research funding (grants + assignments) came from external funding sources. In 2019, five funding sources accounted for 83% of external financing, with FORMAS being the single largest, followed by the Swedish Energy Agency and MISTRA Vinnova and EU. These types of funding often have a longer scope over time and concern larger amounts, which is in line with SEED's goals. Although the department looks favorably at such a large share of external funding, it also feels a large limitation of the small internal funding, especially

basic grants, which greatly limits “free” research and also teaching (due to the difficulty to acquire new faculty positions). Such funds are important to give greater freedom in research, which is needed for advancing the research fields as well as maintaining its position in society.

Following the recommendation from the topical review (ämnesutredning in Swedish) 2016 and the short-term goals that were set, SEED has established an annual SEED day where research, collaboration, and strategic issues are discussed jointly by SEED’s staff. At a later stage, the SEED council was formed to be a platform for academic development (discussing suggestions from the management group and bringing forth suggestions of its own). The council consists of all senior staff and staff with management assignments. SEED thinks that a well-working academic culture influences the quality of research. However, where this academic culture is found varies within SEED. Some researchers feel that SEED, although still in a development phase since reorganizing, has improved its academic culture and that there are low barriers to connect senior researchers with younger researchers, Ph.D. students, and master students. However, the tradition around seminars has differed between the former divisions, and this is still visible. Meeting places for research discussions are the SEED seminars, Ph.D. seminars, but also more informal meetings such as the divisions and department’s coffee breaks and lunches taken in the common lunchroom. Since the topics are diverse in the Department, a variety of meeting places is positive. However, overall, the academic culture at SEED is fairly weak, and it is difficult to get senior researchers to get involved in seminar series. It seems that conferences, research project groups, and external partners are where the academic culture occurs, and this could entail a lack of continuity when projects end.

SEED has eight professors, 2 adjunct professors, and one guest professor. Eight of them are men and three women (Figure 3). Age ranges from 50 to 66, the average (and median) age is 58 years old. SEED has eight associate professors (3 male and 5 female) and one assistant professor (female) as well as one adjunct (female). Age ranges from 40 to 62 years. The average age is 49 years, and the median age of 47, 5 years. SEED has 26 permanently employed researchers; 58% women and 42% men. The average (and median) age is 47 years old. 19 are employed full-time, whereas the remaining seven work part-time (between 20 and 80%). SEED also has two senior male researchers (emeritus professors) aged 68 and 73 years old. 23 employees have the docent title, evenly distributed among men and women. The average age is 56 years old, and the median age is 57 years old. Both the prefect and deputy prefect are female.

In summary, overall, SEED has a good gender balance. However, men are more represented in the highest positions (professors and senior researchers). Therefore, more women should be encouraged to

qualify as professors, and there is a large potential of female professors looking at the category of associate professors. One female associate professor left SEED at the end of 2019. One professor recently retired, one will retire during 2020 and one more during 2021.

SEED has a lack of faculty and also struggles to fill the positions that are left due to retirements or other reasons. At the moment, however, SEED is recruiting two associate professors to replace vacant positions: in technical geosciences and sustainable urban development and has plans to recruit two more to replace retiring/leaving faculty: water and wastewater technology and environmental management (see table 2).

SEED has the infrastructure needed in terms of computer hardware and software, communication support, subscriptions, localities, travel, course management, and very good meeting room facilities. The video conference infrastructure could be improved. The high overhead cost for premises is also a problem and decreases competitiveness in attracting funding.

The lab infrastructure at SEED cannot be classified as good in an international comparison. A new house was built for the SEED department but without facilities for laboratory experiments and with a minimum of storage facilities for equipment. SEED had to get rid of most of the field equipment and cannot today make suitable field sampling, borehole investigations, test pumping, or any hydraulic tests. There is still some quite modern geophysical equipment, including geo-electrical instruments, ground-penetrating radar, electromagnetic instruments, etc. but almost no place to store it and absolutely no place to repair the equipment, charge batteries or maintain it. In comparison to other technical universities, especially internationally, this is a serious threat.

SEED has access to laboratory facilities on the campus and outside:

- the SEED/Water Centre Laboratory at KTH campus is built and equipped for geological (mainly soil) and chemical analyses but also small experiments. The lab is also used in undergraduate courses.
- the STA road research station, a research facility (not directly linked with SEED) with an array of measurement devices on the E18 highway between Enköping and Västerås.
- the “Sjöstadsverkets” facility for tests of advanced equipment and processes in water and wastewater treatment has a large-scale, industrial approach. Our research area concerning wastewater treatment is rather aimed for small-scale solutions, and this facility is therefore not appropriate, especially when the main operator IVL is charging high costs when experiments are performed there.

- the chemical laboratory with field equipment for field measurements in streams (e.g., flow meters, hydraulic conductivity, rhodamine meter, etc.). To keep the field geophysical equipment up to date, which, however, also is necessary for the education programs, there is a need for investments, e.g., in a modern seismic equipment, a gamma spectrometer and a terrameter (for resistivity), in total about 800 000 SKr.

The SEED/Water Center lab has some old equipment that has to be replaced and the lab furniture incl. fume hoods are also out of date.

The administration of the labs is problematic as it takes valuable time from research. There is no permanent staff taking care of its administration and operation of instruments more than one person having 20% employment.

The most important facility support concerns the economy, especially helping researchers with project budgets and follow-ups, which has been defective the last three years. Accessing the economy support is currently and has been extremely challenging and severely affects the external projects in many ways. This is at the school level but has negative impacts on the performance as well as on making future research plans and recruitments.

4. Strategies and organization

SEED has set four long terms (strategic) goals for 2025:

(1) Position SEED as a strong and highly respectable academic institution within KTH, regionally, and internationally in the area of sustainable development, environmental sciences, and engineering. Means to achieve this goal include: dissemination of research and impact cases, high profile research projects and collaborations, improve internal collaborations.
(2) Attract and install the most competent staff/faculty in SEED to support excellent research and education in the area of sustainable development, environmental sciences, and engineering. Means to achieve this goal include recruitment of new faculty to make up for retirements, etc., install new faculty positions, welcome researchers with relevant projects, and high impact.
(3) Develop SEED into a stimulating, well balanced, and yet diverse work environment with a culture of equality, openness, critical thinking, and debate in the area of sustainable development, environmental science, and engineering. Means to achieve this goal include: use the SEED council to discuss academic culture and quality issues, develop SEED seminars, and work on organizational development.
(4) Combine and integrate social and natural sciences and engineering disciplines, detailed and systems-level studies, and technologies for innovative solutions that facilitate a transition to sustainable

development. Means to achieve this goal include: encourage increased research cooperation within SEED.

KTH and the ABE school have high ambitions concerning research on and for sustainable development. SEED sees itself as the hub for these ambitions and also wants to assist the rest of KTH in these ambitions. For example, researchers at SEED take an active part in KTH-internal projects to decrease the climate impact of the university.

Each division has a head of the division, and the department is led by a prefect with support from a deputy prefect (Figure 1). These six people make up the small management group. In the large management, the group is also included: head of administration, director of studies (Ph.D.), director of studies (undergraduate), chairperson of seed council, Ph.D. representative, and representatives from dean's office (economist and HR specialist). The SEED council is a group comprised of all faculty, senior researchers, and those with leadership functions. It is a group for collegial discussions (e.g., on SEED vision, connection to SDGs, new faculty positions). This is a new construct at SEED and has yet to find its final forms. The chairperson of the council struggles to attract senior staff to the meetings. Each head of division conducts division meetings at least once a month. The prefect and deputy prefect holds informal department morning meetings once a month to give updates and capture new developments in the department. Seminars are organized for Ph.D. students in one of the Ph.D. programs and in some topic areas. There is also a SEED seminar series, however dormant at the moment.

SEED highlights new publications in the monthly newsletter and on SEED's website. Open access publication is strived for. Due to the specific history of SEED, there are still differing Ph.D. programs and different ways to work with quality. More work has to be put into the integration of these research cultures, and the SEED council is an important platform for this work. In order to do this, more senior staff needs to attend SEED council meetings. In addition, SEED strives for a more lively seminar culture, which is now missing.

5. Interaction between research and teaching

Teaching and research at the department interact in various ways, which benefits both education and research, e.g.:

- research presented in courses at basic/bachelor and advanced/masters level
- students involved in research projects through basic/bachelor thesis work
- students perform research in advanced/master's thesis work

- courses at an advanced level based on research at the department
- Ph.D. students take part in teaching at a basic and advanced level

6. Impact and engagement in society

SEED conducts interdisciplinary research at the intersection of environmental issues, societal change, and technological innovation focused on developing more sustainable social systems. SEED gathers a broad range of interdisciplinary expertise. Most of the research projects are conducted in collaboration with practitioners, which makes the research relevant and useful to society at large and to specific actors. All dimensions of sustainability are targeted. No specific key external stakeholders or end-users are prioritized or focused on. As most of the SEED's funding is external, and one of the criteria of funding agencies is relevant to society, SEED projects can be argued to be relevant to society at large.

The department's strategy for communicating research is to use general KTH communication channels to reach beyond academia. In addition, SEED researchers use numerous channels to communicate research beyond academia.

SEED considers all of its research to be related to sustainable development and the SDGs. Figure 4 shows the number of SEED publications in 2018 related to different SDGs.

SDG 13: Climate action

SDG 15: Life on land

SDG 7: Affordable and Clean energy

SDG 14: Life below water

SDG 11: Sustainable Cities and Communities

SDG 9: Innovation and Infrastructure

SDG 17: Partnerships for the Goals

During 2019 an initiative was started by the SEED council to map researchers/research projects/thematic areas to the SDGs. This work has not been finalized but maybe a catalysator to develop cooperation within SEED and the need for stronger research groups.

There are many impact cases worth mentioning at SEED. Below is a selection to try to cover the different research areas and stakeholders involved.

- For the built environment, SEED has been involved through several projects in the development of certification systems for buildings, involving a wide array of stakeholders.
- Miljöbyggnad is a classification system that affects three main areas for newly produced or existing buildings: energy, indoor environment, and materials. Within these areas, 16 different aspects are assessed, and all are weighed together to a final grade, which will be classified either as gold, silver, bronze. Miljöbyggnad is now Sweden's largest system for certification of buildings, with more than 1500 buildings certified.
- Citylab is a more recent certification scheme for both newly built and existing neighborhoods. Besides the sustainability of buildings, it also covers areas such as the inhabitant's travel habits, how safe they feel in their neighborhood, how the biodiversity is affected, etc. Citylab is a certification of both the planning and implementation process and the actual neighborhood once built. The project takes place in collaboration between KTH, SLU (the Swedish University of Agricultural Sciences), and SGBC (the Swedish Green Building Council) and involves SGBC's member organizations through working groups. Citylab is currently used in more than 20 city development projects.
- SEED also developed environmental declarations for building materials for new buildings. There is a new regulation on climate declaration for buildings, which shall be effective by 2022 and where SEED has been highly involved in designing the method that should be used (simplified lifecycle analysis). The increased political will to introduce regulation to promote the reduction of climate impact from construction of new buildings was largely due to a series of LCA studies of buildings performed by SEED in cooperation with IVL, Sveriges Byggindustrier and a large number of construction sector stakeholders. SEED is currently commissioned to write a road map for the development of this regulation in Sweden and collaborate with the Nordic countries to promote Nordic harmonization on this topic.
- KTH SEED has a strong research group with numerous projects on macroalgae for a bio-based society. The Seafarm project is an interdisciplinary project that includes marine biologists, chemists, food scientists, engineers, and economists from four universities ¬ KTH, Chalmers, the University of Gothenburg and the University of Linnaeus. The project also has 13 partners from coastal regions in the west, south, and east of Sweden. These include regions, municipalities, and companies. The overarching goal of this project is to develop a sustainable system for the use of seaweeds as a renewable resource in the future, bio-based Swedish society. The transdisciplinary research approach includes techniques for cultivating seaweeds to be used as a raw material in a biorefinery for the production of food, feed, bio-based materials, and bioenergy. In parallel, a general multi-process sustainable assessment method has been developed to analyze the overall sustainability of the system.

- Seaweed farming circumvents several disadvantages related to land-based biomass production, e.g., the need for fertilizers and irrigation, and does not compete for valuable arable land. In addition, seaweeds grow fast, and their farming counteracts coastal eutrophication. A holistic approach is used where utilization of the resource is maximized in each step of the cycle. The research has been qualified for the Royal Swedish Academy of Engineering Sciences' (IVA) top 100 list.
- An International example of research produced at the department with an impact on society at large is about the removal of arsenic and fluoride from drinking water sources in Bangladesh and Tanzania in 2007–2020, two projects funded by the Swedish International Development Cooperation Agency (Sida).
- The Sustainable Arsenic Mitigation (SASMIT) project ran during the project year 2007-2015 and was conducted in collaboration with the NGO Forum for Public Health (Bangladesh), the University of Dhaka (Bangladesh), and Ramböll Sweden AB. The project included the important social components: (i) understand the current pattern of water options and livelihood and thereby identify the areas where the demand is high considering safe water access to optimize the sites for new well installations to maximize the number of beneficiaries; and ii) capacity building of the local drillers who are the main driving force of tubewell installations within the local communities in Bangladesh and many other countries in South Asia. Based on action research in collaboration with local drillers in Bangladesh, a novel handheld Sediment Color Tool was produced to facilitate the local drillers to target safe aquifers for safe tube-well installation. The outcome of this project has been presented as an example of results on the Sida website. The Development of affordable adsorbent systems for arsenic and fluoride removal in the drinking water sources in Tanzania (DAFWA) project investigates and optimizes the use of low-cost affordable adsorbents to remove fluoride and arsenic from the water first at laboratory scale followed by the construction and testing of a pilot water defluoridation plant. The project runs between 2015 and 2020 and is conducted together with the University of Dar-es-Salam (UDSM), Tanzania.