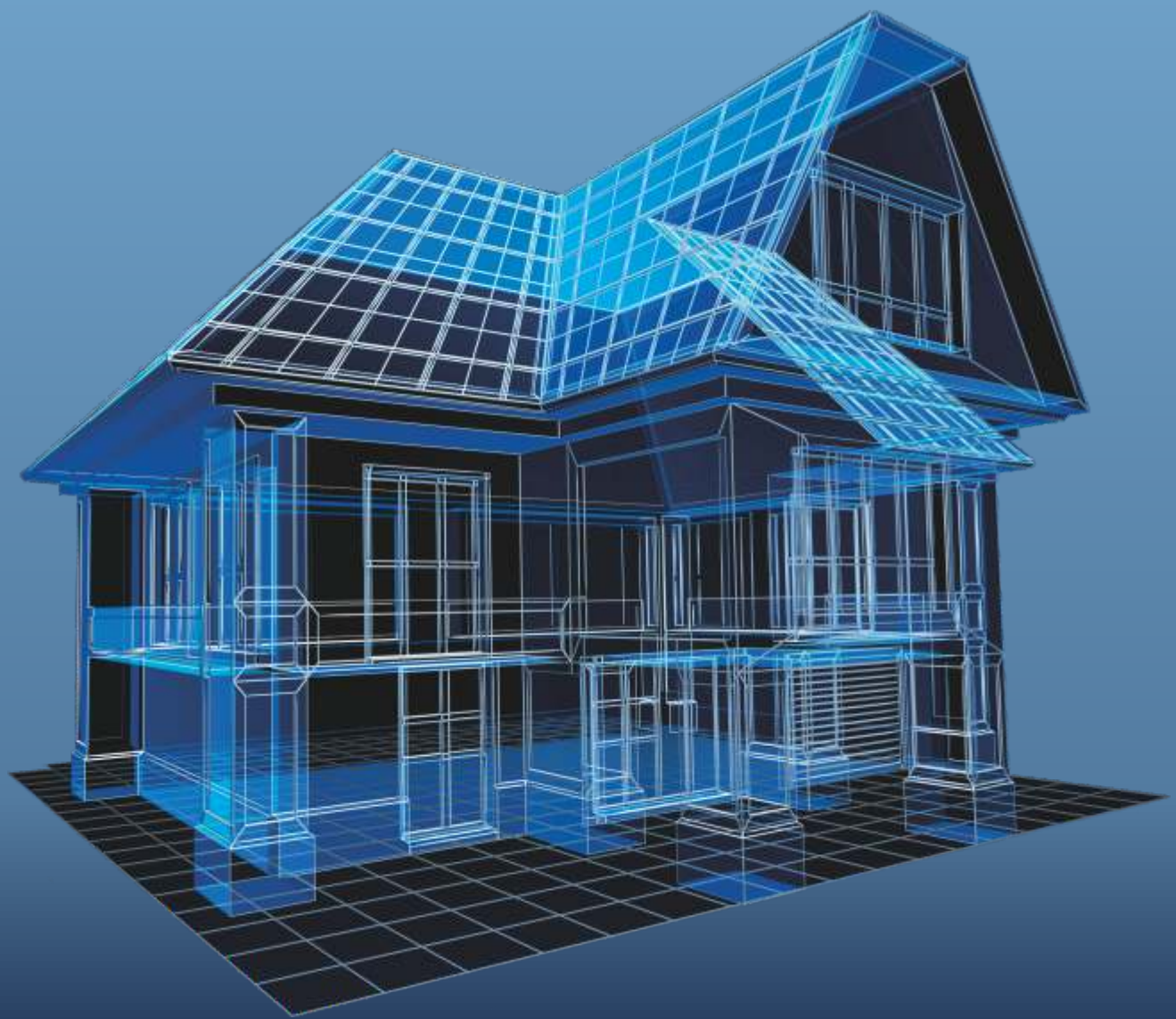
Evaluation of Research in Civil Engineering in Estonia 2008-2012

Evaluation Report 3/2014



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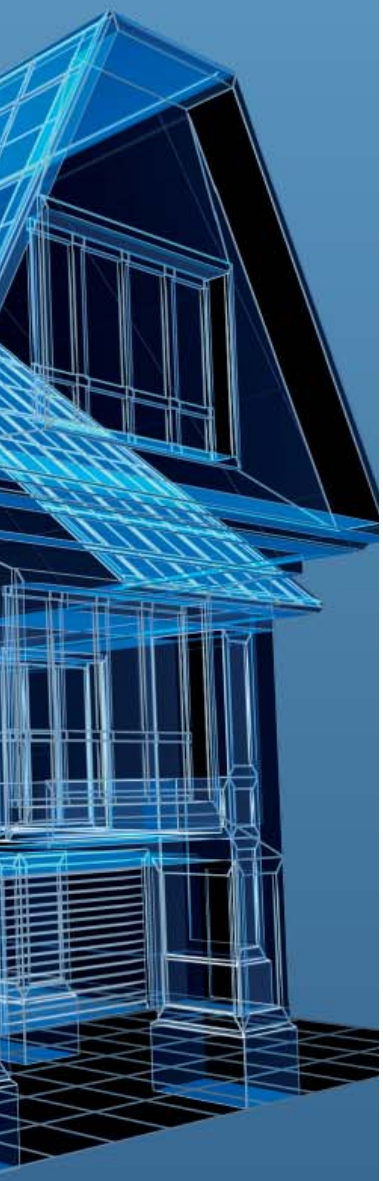

Evaluation Report 3/2014

EVALUATION OF RESEARCH IN CIVIL ENGINEERING IN ESTONIA 2008–2012

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Preface

The Estonian Ministry of Education and Research commissioned in 2013 an international evaluation of research in civil engineering in Estonia. The evaluation was carried out in cooperation with the Ministry of Economic Affairs and Communication, Estonian Research Council, Estonian Higher Education Quality Agency and State Real Estate Ltd.

The goal set for the international evaluation by the Steering Committee was to assess the research quality, the significance of public and professional activities to Estonian society, quality and relevance of training of young researchers and the future potential of the institutions. The institutional assessments involved Estonian Academy of Arts, Estonian University of Life Sciences, Tallinn University of Technology, University of Tartu and Tallinn University of Applied Sciences. Site visits took place during 24-29 November 2013.

The international Evaluation Panel was chaired by Professor Alistair Borthwick from the University of Edinburgh. Where sufficient evidence was available, the Evaluation Panel generally applied the following five-level grading system to assess the Scientific Quality of Research (nationally and internationally), Interaction between Research and Society, Research Environment and Organisation of Research, Quality and Relevance of PhD (MSc) Education: Unacceptable, Moderate, Good, Very Good, and Excellent. In some cases, the Panel used the terms Nationally Leading, Rudimentary, and Supportive as levels more fitting to the gradation. Where insufficient evidence was available, the assessment is recorded as Non-applicable. Regarding the subject of the evaluation the areas constituting the wet side of civil (environmental) engineering, such as water and wastewater treatment, land remediation etc., were not included in this evaluation and will be evaluated as a part of some other evaluation in future.

Steering Committee is happy that all Estonian research and educational institutions in the domain, sometimes with quite different profiles and functions, were involved, making it possible for the Evaluation Panel to see a holistic picture in the full sector with growing importance. On behalf of the Steering Committee I would like to thank all panel members for their commitment to take on the task, and their comprehensive and highly solid contribution throughout the evaluation process. Syntheses of that valuable work have evidently provided new and fresh ideas for systemic development of a large and scattered domain of civil engineering.

Professor Jarek Kurnitski, Chairman of the Steering Committee

Tallinn, March 2014

1 Introduction

1.1 European Construction Sector

Worth at least 1.3 trillion Euros in yearly turnover (2010), the European construction sector and its extended value chain (e.g., material and equipment manufacturers, construction and service companies) constitute the largest European single activity (9.6% of GDP) and industrial employer (30.7% of industrial employment). Furthermore, the constructed environment affects the life and work of all EU-citizens. The construction sector also has a crucial impact on EU environment and energy policies because buildings are responsible for 40% of EU's total energy consumption, and generate 36% of greenhouse gases in Europe, whereas the replacement rate of the existing stock is very low (1–2% per year).

The construction sector is on the critical path of decarbonising the European economy by 2050. In order to achieve this objective the sector must reduce its CO_2 emissions by 90% and its energy consumption by as much as 50%. This is a unique opportunity for sustainable business growth, provided that products and related services for both new and refurbished buildings are affordable and of durable quality, in line with several current or future European directives. Yet, together with the 2050 deadlines, such directives are putting additional constraints on a sector which is directly impacted by the on-going financial and economic crisis, noting that, although Europe has several major construction companies, the sector is highly fragmented, with over 95% of the companies being SMEs.

Given that the construction sector contributes almost 10 % of GDP, the self-assessment information from the evaluated universities appears to show a very inequitable underfunding of civil engineering and construction research in Estonia.

The European Commission and Parliament have adopted several directives which set requirements to member states, such as the Energy Performance of Buildings Directive (2002 and 2010), Use of Renewable Energies Directive (2009), Eco-design of Energy Related Products (2009), Energy Efficiency Directive (2012) and Energy Labelling (2010). Civil engineering is the key to implementing these directives in Estonia. Basic, focused research is also needed in order to implement these directives in a feasible, cost effective way. In a small country like Estonia, integrated innovative research with an international impact should be possible, provided the basic resources are made available.

1.2 Importance of the Construction Sector to the Estonian Economy

In 2011, almost 7% of all employees in Estonia were employed in the construction sector (almost 42,000 people from the national total of 609,000 employees), including about 7,500 persons who possess a degree in civil engineering. The floor area of dwellings completed in 2012 was 233,000 m^2, corresponding to about 180 m^2 per 1000 inhabitants. In 2011, construction-related activities in Estonia at current prices amounted to 1,66 billion euros, including 702 million € directly related to civil engineering.

Estonia has inherited a large number of concrete panel and brick houses from the Soviet era. The studies undertaken to investigate their technical situation have been reported solely in Estonian. The problems concerning Soviet era houses have been mapped quite satisfactorily, and renovation solutions for such houses have been proposed. These solutions mainly include improving the indoor climate and insulating walls and roofs. During 2010–2013, about 540 public buildings were renovated (investment amount 166 million €). To date, no renovated buildings meet the criteria of nearly zero energy buildings.

Estonia imports natural gas and fuel oil that are used in thermal power plants as well as in local heating units. Improvements in energy efficiency should lower the overall heating demand and hence also decrease the dependence on imported fuels. Cheaper solutions based on wind and solar energy sources could also reduce energy imports. Alternative natural sources of energy like logs, wood chips, wood pellets, biomass and peat are widely used for heating (mainly in households, but to some extent also in boiler houses). Oil shale is mainly used for the production of electricity.

1.3 Priority Growth Areas in Estonia

Energy efficiency, simulation, building information modelling (BIM), green building, and human well-being are general growth trends both in Estonia and abroad. Innovative construction and smart buildings have been determined as priority growth areas in the new Estonian strategy for Research, Development and Innovation. The Evaluation Panel makes the following comments about whether present (and intended future) research carried out in Estonian institutions support these trends:

Energy efficiency. The Evaluation Panel believes that Estonian universities are carrying out research that supports national growth in the civil engineering sector related to energy efficiency of buildings. The majority of this research is of a technically high level, but oriented primarily towards applications, with less effort aimed at basic research. This applied research serves the development of Building Standards and Codes, and aims at finding best-performing technical solutions for the construction industry. Some of the results are attracting international attention, particularly from collaborators in the EU. Several institutions are endeavouring towards achieving nearly zero energy buildings (nZEBs). The nZEB tests are being undertaken from an engineering perspective, but there also needs to be included in research on the effect of energy efficient buildings on humans (e.g., thermal environment, noise, light, indoor air quality, comfort, productivity and **human well-being**). This needs a more integrated multi-disciplinary effort, supported by health and social scientists, and psychologists.

There is evidence of research leading to **simulations** that are at different stages of development at different universities. Modern developments in GIS and geodesy have been used at Tallinn University of Technology and the Estonian University of Life Sciences to survey Estonian territory. State of the art models are being used for building performance simulation at University of Tartu and TUT, the latter of which is developing models based on theoretical and experimental work. At the University of Tartu, research concerning the use of CFD for air flows in buildings is performed, which should lead to a better knowledge of indoor fluid flows through detailed parameter studies. The Evaluation Panel was particularly impressed with the internationally leading simulations of ocean and coastal basin hydrodynamics (applied to the Baltic Sea and Gulf of Finland, for example) undertaken by the Wave Engineering Laboratory at TUT.

Although **BIM** is under consideration (e.g., the development of a digital building laboratory for BIM at TTK UAS), the Evaluation Panel observed that integrated BIM is not yet a major area of research activity in Estonia, and that the results do not appear to be taken up by industry (as evidenced by the discussion with a representative of industry during the visit to Tallinn). It is the stated intention of TTK UAS and TUT to carry out future research in BIM. For example, the Faculty of Civil Engineering at TUT is already in discussions with the Ministry to obtain specific funding to assist industry training and research in this field. The Department of Architecture and Urban Studies at TUT states that it intends to investigate nZEB and BIM for energy-saving smart housing. The Department of Logistics and Transport at TUT also refers to future interest in BIM.

The Evaluation Panel found that there were pockets of research aimed towards **green buildings**, but observed that much more should be done to coordinate research on sustainable buildings, paying attention to the joint needs of environment, economy, society and institutions. The Estonian authorities are working on an Estonian version of BREEAM and the universities currently play a role in this. The Evaluation Panel believes that the resulting Estonian system should be compatible with the mainstream activities in other EU countries, and must adhere to EU regulations and European standards. The effect of scale on sustainability must be taken into account: i.e., from building, to street, to neighbourhood, to city. Similar projects are underway at MIT, for example. The need to integrate research focusing on existing buildings' performance, renovation, operation and maintenance should also be carefully investigated.

Human well-being has many dimensions from landscape to room-scale. Related research activities are spread over various Departments of Architecture and similar studies in Estonia regarding aesthetics, culture, and energy efficiency. There is an opportunity for performing research on the quality of life in urban areas. Environmental sustainability needs a multi-scale approach, ranging from the house to the scale of the urban project (and district) and the city.

Assessment: Overall, the research undertaken in Estonia does follow the trends toward innovative construction and smart buildings that have been determined as priority growth areas in the new Estonian strategy of RD&I. This research is *nationally leading*, but needs further priming to be internationally competitive.

Commendation: The Evaluation Panel commends the level of research in the area of energy efficiency, particularly with respect to the integrated approach involving more than one laboratory.

Recommendations:

(1) The continuation and expansion of research in the closely-related areas of automatic controls and sensors (smart buildings), community planning, heat and electricity production.

(2) Estonian authorities should collaborate with Nordic countries to follow on-going research on BIM that integrates all its constitutive aspects, including structural, architectural, building services, geotechnical engineering, maintenance, integrity, information engineering, etc. Effort should also be made to integrate BIM properly in relevant civil engineering courses, and continuing professional development.

1.4 Research Deficiencies

The primary deficiencies are a lack of fundamental research (reported in the top journals), limited innovation, and the slow completion rate of PhDs (the latter could be partly overcome through more creative funding mechanisms). Systemic problems are evident in the universities due to the way in which they have been structured historically. It should, however, be noted that Estonia has invested in a new generation of academics and researchers, who offer opportunities for a flatter, more research-intensive future. At present, there is a lack of integration of civil engineering research activities on innovative construction and smart buildings across Estonian universities, which means that opportunities that could arise from creating critical mass are lost. The effort is primarily toward applied research funded by narrowly-focused short-term projects without enough attention paid to the need to bring forward basic research in an integrated way. Collaboration between the universities and external partners could be much wider to promote innovation. Overall there was evidence of a lot of application, but not enough innovative development. Although the standards of civil engineering research (within the limits examined by the Evaluation Panel) are nationally leading, almost no research is internationally leading (except for limited examples, such as the Wave Engineering Laboratory). This is of course a reflection of the economic potential of a relatively small economy, and should not be taken as a criticism of the research effort.

There is a general dilemma between contract testing and research. These activities are usually undertaken in separate units, except in Germany where both are undertaken at universities. On the negative side, testing takes up human resources otherwise available to research. On the positive side, testing may generate some income and concentrate facilities in a single institution. A problem specific to civil engineering research is how to serve practice and science simultaneously? In the building sector, publicly-funded research which serves SMEs is needed.

Recommendations:

(1) to co-operate more with external leading groups abroad in order to generate critical mass. There are potential opportunities in knowledge/innovation transfer (in the road, building and rural engineering sectors) to the economic benefit of Estonia by exploiting the proximity of Russia as a potentially huge market.

(2) that research related to civil engineering be clustered around shared facilities such as the nearly-zero energy building at Tallinn University of Technology.

1.5 Education of PhD and MSc Students

The Evaluation Panel reached the following conclusions about the education of PhD and MSc students in the civil engineering areas considered. In certain cases, the thesis covered a very wide topic, meaning that the student's work remained at a rather shallow level. Better-focused and narrower topics would create an opportunity to undertake scientific work in a more concentrated way, leading to publications in prestigious journals.

At the PhD level, the literature review should have much more thorough coverage of the scientific literature. It would also be beneficial if the student could continue the same topic area in the PhD thesis which was initiated in the MSc level. There is definitely a need for better preparation

of students for undertaking research, scientific writing and the correct use and referencing of trustworthy sources. This has to be done in the MSc education and doctoral schools.

Doctoral schools should not be merely limited with the administration of the student selection and financial assistance to students. The schools should also organise courses on selected topics which support the national research policy, using teachers from different universities in Estonia and abroad. Internationally-recognised experts/scientists should be invited to give lectures on these courses. Where appropriate, the introduction of international experts as members of the supervisory teams of PhD students should also be considered. The use of communication media such as Skype and WebEx can make this a technically and economically feasible option. More student and staff exchanges would help invigorate graduate research from a more international perspective, and could perhaps be pursued more aggressively through Erasmus and other European programmes.

PhD students receive a stipend of 384 €/month for a maximum of 5 years. Many obtain a supplementary salary from the research funds of their supervisor or from teaching activities. Students are expected to produce a minimum of 3 papers, of which at least one as the first author. PhD studies take on average more than 4 years, mainly due (according to the interviewed students) to the low level of the stipend which means that they seek out other employment to supplement their income.

Recommendations:

(1) MSc thesis topics should be more science- than design-orientated.

(2) MSc theses must include a relevant literature review containing a critical discussion of relevant publications in top scientific journals, and not be limited to Estonian publications.

(3) Joint doctoral course development in cooperation with other universities covering research methodology issues and state-of-the-art technologies for specific topics.

2. TTK University of Applied Sciences

The Evaluation Panel was impressed with the courteous reception, extensive tour and well-prepared documentation it received at TTK University of Applied Sciences.

2.1 Scientific Quality of Research

TTK University of Applied Sciences is primarily a teaching institution, offering 4-year courses, but no MSc or PhD programmes. The number of civil engineering-related research-active academic staff at TTK UAS has increased from 9 in 2008 to 16 in 2012. The staff's demographic profile is very young. TTK UAS undertakes applied research primarily for small- and medium-sized companies and government agencies. This research is closely related to the needs of the Estonian road construction, timber, and mining industries. External research funding to TTK UAS has increased from 24 thousand to 236 thousand €/yr over the past 5 years. However, although such applied research is particularly valuable to Estonia, the outputs cannot be yet classed as international. Many of the early-career staff members at TTK UAS are themselves studying for doctorates (supervised elsewhere, usually Tallinn University of Technology, TUT). One anomaly is that the publications of the early-career staff members are submitted under TUT rather than TTK UAS even when TTK UAS funds the salaries and perhaps contributes to the conference fee.

The self-assessment did not summarise any significant scientific achievements. Instead, the four achievements listed were primarily concerned with enabling mechanisms to improve the research environment (i.e., the road construction laboratory, a digital building laboratory for BIM, and a mobile laboratory to assess building conditions), collaborations with State authorities and private sector industries, innovation related to SMEs, and a young lecturer's programme (one lecturer having completed a doctorate, and six underway). During the site visit it was obvious that several staff members are on the way to producing scientific achievements, particularly in the area of Road Construction & Materials Engineering, and Structural Testing, where there is clearly evidence of infrastructure being put together.

No information regarding the CVs of individual staff members was given in the self-assessment. The self-assessment indicates that 3 journal articles, 5 books/monographs, and 16 articles in proceedings were produced during the 5-year period from 2008 to 2012. In a research-led University this would be very low indeed. However, the Committee is aware that TTK UAS is a teaching-led university, and, moreover, the published outputs have been underreported. There is one patent.

Assessment: TTK UAS is producing research outputs related to civil engineering that are *Very Good* in the national context, and *Non-applicable* at the international level due to the lack of MSc and PhD programmes.

Commendation: Staff members at TTK UAS are to be commended for attempting to construct research laboratories with relatively limited funding, almost entirely through their own efforts and assistance from students.

2.2 Interaction between Research and Society: Public and Professional Activities

There are strong national collaborations with SMEs, the Estonian Road Administration, Tallinn University of Technology, and the Technical Centre of Estonian Roads. The Institution makes good use of the innovative voucher system offered by the State, which promotes the cooperation with SMEs. TTK UAS staff members are involved with many professional bodies (though details were not given in the self-assessment of the exact number of academic staff involved), conferences (on building energy efficiency, roads, materials, BIM, etc.), an annual student bridge-building exercise, and Continuing Professional Development courses.

Assessment: Interaction between research and society at the TTK UAS is *Very Good* at the national level.

2.3 Research Environment and Organisation of Research

TTK UAS has a research environment commensurate with a teaching university. Investments have been made into a Road Construction Laboratory and a Building Structures Laboratory (with Test Rig costing 285 thousand €). In the future, TTK UAS intends to carry out research on road, bridge and other structures using the new facility. There will be a focus on wood and concrete composites, energy efficiency of buildings, building information modelling (BIM) in cooperation with TUT, while it is aimed not to overlap with the research activities elsewhere in Estonia. Another aim is to grow research-active staff through taking on up to 5 new members of research staff within 6 years, and to replenish the laboratories with new equipment. The TTK UAS supports the research activity of teachers by adjusting the teaching load according to research activity and outputs.

Assessment: Although the overall research environment at TTK UAS is *Rudimentary*, the organisation of research is *Supportive*.

2.4 Quality and Relevance of PhD (MSc) Education

There are no MSc or PhD programmes at TTK UAS. Its graduates and teaching staff members willing to study at PhD level can apply at TUT, undertake a MSc degree first, and subsequently combine the use of facilities at TTK UAS with research supervision at TUT. It is the ambition of TTK UAS to enrol more PhD holders in the future. The Evaluation panel stresses the importance of not losing focus on TTK UAS's actual SME niche in industry.

Assessment: *Not applicable*.

2.5 Recommendations and Future Potential

TTK UAS occupies a niche area in the research field in Estonia that focuses on serving SMEs, and perhaps also by providing testing services for industry. The postgraduate studies of the staff members who are also research students will most likely improve the level of teaching.

Recommendations:

(1) TTK UAS should continue the practice of adjusting the teaching load of academics according to research activity and achievements.

(2) The level of degree attained by the academic should be reflected in the salary (to incentivise completion of PhDs).

(3) Academics who are also PhD students must also include the name of their employer in their publications.

(4) TTK UAS should investigate ways of collaborating further with TUT to promote internationalisation of its R & D activities and thereby enhance the benefits to the Estonian economy. More participation as a partner with TUT in EU level projects would be beneficial, specifically in dissemination and demonstration projects (e.g., Intelligent Energy Europe).

(5) The Evaluation Panel stresses that it is important for TTK UAS not to lose focus on its niche role in supporting SME industry.

3. Estonian Academy of Arts

The Evaluation Panel was impressed with the courteous reception, extensive tour and well-prepared documentation it received at The Estonian Academy of Arts.

3.1 Scientific Quality of Research

The number of civil engineering-related academic staff at the Estonian Academy of Arts has increased from 20 in 2008 to 25 in 2012. Research funding increased from 143 thousand €/yr to 322 thousand €/yr over the same period. In 2008 all the funding came from Estonian sources. By 2012, about one-third of external funding was from the EU. This all indicates expansion. Research activities at the Estonian Academy of Arts focus on (1) practice-based research (the arts side) and (2) the history and philosophy of architecture, habitation patterns and urbanisation. The practice-based research is directed towards computing morphogenesis with a strong emphasis on artistic production and making use of up to date software and state of the art 3D digital modelling equipment. The research methodology is "research by design" and this has led to the involvement in a € 4 million EU programme for developing this new methodology within a European consortium of schools of architecture. Research into the history and philosophy or architecture includes the study of the evolution of Estonian settlements (in particular Tallinn), critique of 20th century art and architecture, and analyses of the cognitive and conceptual aspects of architecture.

The staff members have produced 64 journal articles, 30 books/monographs, and 75 articles in proceedings. This equates about 3 journal papers, 1.5 books/monographs, and 3.5 articles in proceedings per member of staff over the 5-year period. There is evidence of substantial architectural works: office, institutional, commercial, domestic, and agricultural buildings in Estonia and an office in Amsterdam. The Evaluation Panel recognised the quality of the work produced and formed the view that the research outputs were nationally leading and of a reasonable international standard taking into account the particular situation of architectural research in Estonia. The academy has an artistic and humanities-based approach to architecture. According to the Evaluation Panel, the classification system of disciplines listing architecture under the natural sciences and engineering is not appropriate for assessment of the research strengths of a multidisciplinary subject such as architecture (in particular the art, history, and philosophy aspects of the subject). It would be better to create a category under the name "Built Environment" or a similar title, and concede that schools with different profiles study different aspects of architecture.

The Panel commended the Estonian Academy of Arts for its outstanding achievement in completing a major research project on the urban development of medieval Tallinn (which has led to a series of textbooks, one translated into English). It also noted that the EAA had gained several national prizes for research publications on the relationships between power and architecture in Estonia from 1918 to 1940, the relationship between Man and his environment, and the book "Environment, Projects, Concepts, Architects of the Tallinn School 1972–1985", which won the annual Award of the Estonian Society for Art Historians. Two projects have been awarded the Estonian Cultural Endowment Annual Prize for Architecture.

In the future, the Estonian Academy of Arts intends to pursue further practice-based research: creative practice research with focus on research by design, as well as further research on the history and theory of architecture. In other words, it heads onwards in the same direction. The Estonian Academy of Arts aims to restart a restructured PhD programme in Architecture and Urban Design (linked to practice-based research). The long-term aim of the 3D Lab is also to develop an Institute of Experimental Architecture.

There is evidence of an effort to internationalise the research activities since the last research evaluation. This has been quite successful in that the Faculty of Architecture is a member of the international consortium ADAPT-r supported by EU funding. The Committee noted with approval the employment of a head of research and an R&D coordinator to help enabling the Faculty to penetrate the EU grant market.

Assessment: The research outputs related to Humanities are *Very Good* to *Excellent* at the national and *Good* at the international level. The Engineering-related research is *Not Applicable* in the context of the present evaluation exercise.

Commendation: The Estonian Academy of Arts is to be commended for its outstanding achievements in research on the urban development of medieval Tallinn.

3.2 Interaction between Research and Society: Public and Professional Activities

The Faculty of Architecture is organising a Public Lectures Series on Contemporary Architecture, displays its best work at end-of-year shows, and runs an annual conference. The Faculty has also helped to ensure the survival of the oldest Estonian architecture magazine by taking over responsibility for its publication. Staff members have been involved in juries in London and Melbourne. There are well-established national collaborations with Tallinn University of Technology and the Institute of Technology of Tartu University in practice-based research. The Faculty of Architecture intends to promote further International collaboration through its EU and Nordic connections.

Assessment: Interaction between research and society is *Very Good*, especially with regard to the cultural aspects (again noting the work on medieval Tallinn) and the interactions with architectural practice.

3.3 Research Environment and Organisation of Research

The Faculty of Architecture has a split location with three Departments (Architecture & Urban Design, Interior Architecture and Furniture Design, and Urban Studies) located on five separate sites. A new building to bring all the Departments together was previously envisaged, but has been postponed due to the economic situation. The Committee visited two sites: the Main Building and the Faculty of Architecture. The impression was of young, enthusiastic staff members. The Evaluation Panel visited a library of books (largely related to the art and history

side of Architecture), a 3D geometric modelling facility that was utilised imaginatively by MSc students, and a laboratory linking imaging, architecture and robotics (a working model of an active/responsive wall steered by solar cells). Staff referred to the availability of JSTOR, containing more than 20,000 e-books from known scholars.

Assessment: The research environment and research organisation is *Good* to *Very Good* in the national context.

3.4 Quality and Relevance of PhD (MSc) Education

There is no PhD programme at present, owing to the closure of the doctoral programme in Architecture and Urban Design in 2011. However, there are two students in related areas (Art History and Art & Design). 16 MScs completed in 2012. From the site visit, it was clear that the MSc students were fully engaged and positive about their research. The graduate school is strictly Arts and Humanities. It is currently re-applying for the right to grant PhD in architecture.

Assessment: *Not applicable*.

3.5 Recommendations and Future Potential

Although the profile of EAA is clearly not geared towards the traditional engineering disciplines, EAA should assume full responsibility of the "designerly" (Nigel Cross) aspects of 'new' developments in society and engineering such as sustainability, energy efficiency and BIM. Universal design should also become a part of the research and teaching portfolio at EAA, given the ageing population (that sooner or later will also affect Estonia). These new agendas should not develop separately, but in close collaboration and mutual understanding with more technically skilled colleagues from TUT and/or TTK UAS. This synergy is absolutely necessary in order to achieve results that will be profitable for architecture as well as for engineering.

4. Tallinn University of Technology (TUT): assessement of units

The Evaluation Panel was impressed with the courteous reception, extensive tour and well-prepared documentation it received at Tallinn University of Technology.

Tallinn University of Technology has 13,700 students, of whom 5% are foreign. TUT's overall budget at present is about 100 million €, of which about 40% is related to research and development. TUT has eight faculties, and there has been traditionally a very strong emphasis on engineering. There are several institutes, including ones related to cybernetics and marine systems. The Senior Management is concerned that research funding raised by the Faculty of Civil Engineering was presently only 5.8 % from the research budget of the university, compared to the 10 % share of GDP for the building industry. TUT would like to see a doubling of research income to re-invest back in facilities and to employ more group leaders.

4.1 Scientific Quality of Research

Civil engineering and related research are clustered in the Faculty of Civil Engineering, the Institute of Cybernetics, and in Tartu College. The Faculty of Civil Engineering has the following units: Department of Architecture & Urban Studies (2013), Department of Structural Design (Design of Buildings), Department of Environmental Engineering, Department of Mechanics, Department of Building Production, Department of Road Engineering (formerly the Department of Transportation, on 1st February 2012 it was renamed the Department of Road Engineering), Department of Logistics and Transport (which branched out from the Department of Transportation, since 1st February 2012), the Department of Landscape Architecture in Tartu College, and the Wave Engineering Laboratory within the Institute of Cybernetics.

The number of research-active personnel has increased from 115 in 2008 to 132 in 2013. There are about 1,000 students taking a 5-year MEng course, 270 MSc students and 80 PhD students. From 2008–2012, about 150 students a year graduated with MEng-type degrees, 40 with MScs, and 7 PhDs. However, the number of PhDs has risen towards 15 per year, the increase largely being attributable to the Civil and Environmental doctoral school. In recent years, there have been investments into laboratory facilities. The Faculty of Civil Engineering would like to see further sustainable growth, maintenance of high quality teaching and internationally competitive research. Former staff Members in the Faculty of Civil Engineering founded and currently lead the Wave Engineering Laboratory in the Institute of Cybernetics (which has international-level leadership and outputs). There is a recently established nearly zero energy buildings nZEB group with about 10 staff.

According to the self-assessment, the Faculty of Civil Engineering considers its highest future research priority to be problem-based research related to the Estonian national needs, which mainly concern buildings and roads. International research is the second priority. The Institution will continue to support regional education through its various satellite colleges. The Faculty of Civil Engineering would like to improve the integration of the staff in the Wave Engineering Laboratory in teaching. The Faculty of Civil Engineering would like to merge the research groups concerned

with building physics, HVAC and energy efficiency, and draw a clear distinction between research in fluid mechanics and water systems. It should be noted that the Faculty of Civil Engineering operates an Energy Performance Laboratory that has a collaborative, complementary overlap with the Energy Efficient Building Core Laboratory at Tartu University.

From 2008 to 2012, the external research income increased from 814 thousand €/yr to 2,738 thousand €/yr. By 2012, funding per member of staff was about 15.4 thousand €/yr. The stated research output from 2008 to 2012 was 292 journal articles, 46 books/monographs, and 334 articles in proceedings. This equates about 4 journal papers, 0.65 books/monographs, and 5 articles in proceedings per member of staff over the 5-year period. The research group clustering around nZEB involving three chairs/professors is a sensible step towards the integrated research needed to solve problems related to the energy efficiency of buildings. This is a good continuation of the building performance-related research which has already covered building stock from Soviet times, rural homes, historical buildings, (during recent years) energy efficiency, including deep renovations of buildings, and according to the future plans, shall focus on integrated solutions for net zero energy buildings. An example from this area is the research undertaken on the total economy of windows including heating, cooling, and lighting. The cooperation in this group has also been successful in establishing criteria on moisture transfer in structures. Some of the results of this group have been recognised already at EU level and have had an impact on European standards. With the reduction of direct energy use, indirect energy becomes more important. The latter is reflected in the embodied energy of the used materials. The Building Materials group, experienced in the greening of cement and concrete, is in an excellent position to address the need for low CO_2 building materials, e.g., achieved through saving, substitution (using by-products), recycling, etc.

The research in the area of HVAC, building physics and energy efficiency undertaken at TUT is relevant to the Estonian society and has reached an international level in certain areas. This has been an excellent development during the past few years and should be continued. The strength is the ability of integrated experimental and theoretical work, and the development of models for parametric studies, as well as for solving specific practical problems. Further integration regarding the energy supply side (including the influence of electricity supply on the grid and building level, as well as the optimal use of renewable energies) could be undertaken in the future. The majority of the research in this area has been focusing on the performance and optimal use of existing technology; this is a natural beginning of new research areas, but hopefully this should lead to more innovative research in the future.

Although the operation and maintenance of buildings is an important area of civil engineering, none of the evaluated institutes presented major activities in that area, which is surprising, given the inherent relationships with environmental impacts, human well-being and use of resources. Indoor air quality was mentioned by TUT and University of Tartu. The IAQ topic is huge, and should not be included in civil engineering research without representation of human sciences in the research group. To develop internationally-recognised research in this area takes several years, maybe decades, and may not be feasible for Estonia. The follow-up of international research is, of course, needed to be able to establish targets for engineering research. An exemption, of course, is the safety of purely national building materials, like by-products from power generation, and their environmental impacts.

Comment: The Evaluation Panel was surprised that the report did not cover the very important areas of water supply, water quality, water and wastewater treatment, river basin management, lake hydrodynamics, land remediation, eco-efficient sustainable use of water resources, etc., that constitute the wet side of civil engineering.

Assessment: Tallinn University of Technology is producing civil engineering research outputs that are *Good* to *Excellent* in the national context, and *Moderate* to *Excellent* on the international level, depending on the research area. There is scope for more emphasis on high quality peer-reviewed papers in top international journals.

4.2 Interaction between Research and Society: Public and Professional Activities

The Faculty of Civil Engineering produces about 200 graduate engineers and architects per annum, who take up positions in the construction industry in Estonia. The Faculty acts as a repository for Estonian knowledge and competence on the design and construction of buildings and roads, and also plays a major role in the preparation of national standards (and national annexes to European standards). Its academics are members of various national professional bodies, and some are members of European/international professional bodies. The Faculty of Civil Engineering collaborates with Estonian ministries and public authorities, professional organisations, industry partners, cities and municipalities, and other Estonian universities. The Faculty's most important international collaborations are with partners from Finland, Latvia & Lithuania, Sweden, Germany, Austria, and France.

Assessment: Interaction at TUT between research and society is *Good* to *Excellent* at the national level but *Moderate* to *Good* at the international level depending on the research area.

4.3 Research Environment and Organisation of Research

In general, TUT has a research environment that is unevenly distributed, ranging from the state of the art nZEB laboratory to much less well-endowed facilities. Overall, the facilities appeared fit-for-purpose, well utilised, and clean. Although this is outside the competence of the Evaluation Panel, the importance of following EU health and safety guidelines and legislation cannot be emphasised too highly. Areas of potential concern are the use of lasers in the fluid mechanics laboratory, the need for risk assessments, and the use of student labour to fabricate test equipment and prepare specimens.

All in all, staff morale seemed to be good. It was, however, unfortunate that no explanation was given to the Evaluation Panel in advance on the omission of all research in Environmental Engineering, except for in the field of Heating and Ventilation.

There appears to be a top-down approach to research organisation. International collaboration is going well, but TUT could do better in leveraging EU funding. Closer cooperation with selected international top institutes should be a priority. There is a worry about the retention of key staff, owing to the relatively low salaries in the Estonian higher education system.

Assessment: The research environment at TTU is *Moderate* to *Very Good* in the Estonian context, and the organisation of research appears to be centralised and managed top-down.

4.4 Quality and Relevance of PhD (MSc) Education

The overall number of successfully completed PhDs is 7 per annum (now rising to 15 per annum). A 40-minute meeting was also held with about a half of the total number of PhD students. Low stipends mean that the students have to work (sometimes holding down two other jobs) in order to subsist. It might be better to provide larger stipends to reduce the long periods that students are taking to complete their PhDs—there is a lost opportunity here. It would also be better to consider those students on low stipends as studying part-time, and provide an appropriate extension to the minimum degree completion period. TUT has its own doctoral school operating with a significant budget of > 750 thousand € in the November 2008 to November 2014 period. The students were generally very enthusiastic about their studies and the frequency and quality of supervision given. The students commented that they were well provided for in terms of access to library journals and computer facilities. There would be scope for departmental seminars, preferably student-led, in order to improve presentational skills and help bond the group. Many students are co-supervised, and there is some pastoral care evident, though it may be worth formalising a student advisor system. The students are required to publish three journal papers in order to receive their doctorate. In some cases this requirement may delay the graduation due to the time-lag between submittal and publication.

As the policy of TUT is science-oriented, this should be reflected also in the curricula so that MSc students would have better basic skills for scientific work. As the total number of credit hours (points) is limited in the degree, there is a need for critical evaluation of the contents of the courses. There seem to be some purely design-oriented courses in the programme, maybe for historical reasons, when the main task of the university was to educate engineers for practical jobs. Now the movement towards a science-led university should also change the contents of the basic education. The courses formerly included in the TUT programme may be transferred to the University of Applied Sciences.

Recruitment of PhD students seems to be successful. The Evaluation Panel believes that energy efficiency (nZEB) and environmental issues will create considerable future interest amongst high school graduates with eventual feeder effects to the doctoral programme.

The high dropout rate from the basic studies is alarming: 51.4%. This is a tremendous waste of resources. The reasons for this are unclear but should be investigated thoroughly. The Evaluation Panel believes that TUT is studying the underlying causes with a view of rectifying this problem.

4.5 Recommendations and Future Potential

Recommendations:

(1) The Evaluation Panel endorses the wish by TUT to increase its external research income, particularly from EU funded programmes, and recommends the employment of Research Facilitator(s) (preferably with experience in the organisation and management of international projects) to work with staff within the Faculty to prepare suitable applications and determine the best way to optimise potentially successful applications. Reimbursement of travel expenses would need to be available to help pump prime applications through networking across Europe. The Faculty should consider the long-term opportunities offered by industry innovation vouchers.

(2) The Department of Architecture and Urban Studies at TUT should collaborate with the Architecture Departments at the Estonian Academy of Arts and the University of Tartu to maximise their mutual and complementary expertise.

(3) Efforts should be made by staff members in those subjects affected by declining enrolment (such as Heating and Ventilation and Road Engineering) to engage with secondary schools to promote awareness of these subjects.

(4) The Evaluation Committee valued the productive cooperation between HVAC, Building Physics and Structural Design in the area of nZEB but did not find evidence supporting the necessity of combining Structural Design activities with HVAC, which are normally separated in comparable civil engineering faculties. Nonetheless, should this occur, the Evaluation Panel would recommend that TUT consider renaming the Department of Structural Design the Department of Building Engineering or a similar title (and that all activities related to nZEB be encouraged to migrate there).

(5) **Independent** reviews should be carried out on the Departments of Environmental Engineering and Structural Design before carrying out the reorganisation proposed in the Self-Assessment. A particular concern would be how to achieve a fair balance between the size and scale of different Departments within the Faculty, including the wet side of civil engineering.

(6) PhD and MSc theses should have more strongly focused topics.

(7) TUT should recruit more foreign students.

(8) More seminars and organised doctoral school courses should be established.

(9) An internal review should be carried out into clearly establishing the requirements for each PhD/MSc thesis so that these would match international standards.

4A. TUT: Department of Architecture and Urban Studies

4A.1 Scientific Quality of Research

The Department of Architecture and Urban Studies has been in existence since May 2013 with 9 staff, 7 of whom are new, and so it is too early to judge the research outputs. The Department occupies new premises, and enjoys a good level of applications. The academics are practitioners involved with ongoing building design. In the self-assessment report, the Department of Architecture and Urban Studies states under 'future research' that it will investigate various topics in (1) architecture, (2) urbanism, (3) architecture sciences and education, besides nZEB and BIM for energy-saving smart housing. This work should complement related activities undertaken in the Department of Structural Design and the Chair of Heating and Ventilation, and not overlap with similar research at other Estonian institutions. However, the Evaluation Panel found no evidence so far that the Department of Architecture and Urban Studies has sufficient in-house expertise to undertake high quality research into nZEB and BIM.

Assessment: The research quality was not evaluated because the Department of Architecture and Urban Studies has only been in existence for a few months.

4A.2 Interaction between Research and Society: Public and Professional Activities

Members of staff have been awarded major national prizes; one is a member of the Berlin Academy of Art and the German Academy of Urban Planning. Another is the Founder and Director of the Museum of Estonian Architecture. One member of staff makes a weekly broadcast on Estonian radio and has authored a book on Estonian Architecture. Staff members are clearly enthusiastic, and there is plenty of international collaboration.

Assessment: Interaction between research and society was not evaluated because the Department of Architecture and Urban Studies has only been in existence for a few months.

4A.3 Research Environment and Organisation of Research

It can be gleaned from the self-assessment that the Department would like to have an additional section on architectural literature to be added to the TUT Library, and it requires more study space.

Assessment: The Evaluation Panel was not invited to visit the Department of Architecture and Urban Studies, and there is no assessment possible due to the very recent commencement of this Department.

4A.4 Quality and Relevance of PhD (MSc) Education

Assessment: *Not applicable.*

4A.5 Recommendations and Future Potential

Comment: *Not applicable.*

4B. TUT: Department of Structural Design (Design of Buildings)

4B.1 Scientific Quality of Research

The majority of the research effort in the Department of Structural Design is concerned with building physics, engineering, and energy efficiency. From 2008 to 2012, the number of research-active staff increased from 19 to 26. Grant income increased from 158 thousand €/yr to 707 thousand €/yr. Published outputs included 26 journal papers and 19 books/monographs—about 1 each per member of staff over a five-year period. This is low from an international perspective. There are 122 conference proceedings, and no patents reported. The published output ranges widely in quantity and quality, with a few key staff members having produced the bulk of the Department's reported publications in Category 1.1 journals, and others producing hardly any international publications during the evaluation period. High quality outputs reported in the data submitted to the Evaluation Panel include journal papers on nZEB energy performance calculations (Kurnitski *et al*., Energy and Buildings, 2011), fire-resistance of thermally insulated timber-frame constructions (Just *et al*., *Fire and Materials*, 2012), and moisture convection performance of buildings (e.g., Kalamees & Kurnitski, J. *Building Physics*, 2009). Investments have been made into the Laboratory of Building Structures, the aim being to prime research into the hygrothermal properties and behaviour of building materials and constructions, in keeping with the long-term requirements of the Estonian economy. The main research achievements include research into the indoor climate of buildings, a survey of Estonian building stock, the nZEB project, restoration of the World's first reinforced concrete shell structures, and fire safety of timber and steel structures (informing Eurocodes). The Department's stated future research will be predominantly problem-based, and include nZEB, fire, wood, and HVAC in the context of a greater energy efficiency in buildings. There will also be new research into steel, timber and concrete structures (including shell structures and cable-supported structures) and geotechnical engineering. From the Self-Assessment, the tour of the facilities at TUT, and the presentations by the Head of Department of Structural Design, the Evaluation Panel gathered that the main thrust of ongoing research activity in the Department is building-related in accordance with the Estonian national requirements.

Assessment: The Department of Structural Design is producing civil engineering research outputs that are *Very Good* in the national context, but *Moderate* to *Good* on the international level.

4B.2 Interaction between Research and Society: Public and Professional Activities

Academic staff members are members of European bodies and prepare Estonian regulations, standards, and handbooks. Members of staff are board members of many Estonian professional bodies and sit in scientific committees. There appears to be a close relationship with government agencies and industry. A huge number of collaborations are listed in the self-assessment—far more than what was asked for. There is close collaboration with the City of Tallinn in the area of energy performance of buildings. There are very relevant ongoing collaborations with the University of Tartu and the Estonian University of Life Sciences, as well as universities in Finland and Sweden. Departmental staff members have also contributed to International Energy Agency annexes.

Assessment: Interaction in the Department of Structural Design between research and society is *Very Good* on the national level and *Good* on the international level.

4B.3 Research Environment and Organisation of Research

The Evaluation Panel visited several laboratories, including the Laboratory of Building Structures (a spacious building containing a strong floor used for the testing steel and concrete structures), the new nZEB facility, and climate chambers for hygrothermal and indoor climate tests, and a fire safety facility. These facilities offer an excellent opportunity for research in new areas, cooperation with industry and international partnership. The overall impression of the Department, however, is that they may be perhaps rather too comfortable due to a successful past history; this might reduce the impetus to report research findings in reputable journals.

In its self-assessment, the Department of Structural Design states that it would like to take over HVAC staff/activities from the Department of Environmental Engineering. There is no reciprocal comment in the self-assessment by the Department of Environmental Engineering, which is odd, given that its reported civil engineering-related research is entirely concerned with HVAC and lighting.

Assessment: The research environment in the Department of Structural Design is *Very Good* in the Estonian context, and the organisation of research appears to be *Good*.

4B.4 Quality and Relevance of PhD (MSc) Education

3 PhDs were completed in the past 5 years. One took more than 13 years to complete, another took 7 years. This is far too long. There are presently 12 ongoing PhDs, 4 of whom are jointly supervised by the Chair of Heating and Ventilation (the maximum capacity of current personnel). Problems of duration *are described in Introduction, paragraph 1.5*.

4B.5 Recommendations and Future Potential

The concept of nZEB implies that the production and transport of building materials form a substantial part of the life-time energy use of a building. The Building Materials group is in a position to address the associated need for building materials with a reduced environmental footprint.

Recommendations:

(1) The Department of Structural Design should place more emphasis on its staff members publishing high quality outputs in peer-reviewed international journals. At present the outputs are very unevenly spread between a few high performers and the majority.

(2) The research thrust should continue towards nZEB.

(3) Every effort should be made to reduce the time taken by PhD students to complete their degrees.

4C. TUT: Department of Environmental Engineering

The Self-Assessment focuses solely on HVAC and energy efficiency, as does the stated future research intentions. It was the understanding of the Evaluation Panel that it was to carry out a targeted review of civil engineering and related research in Estonia, and yet core civil (environmental) topics including floods, droughts, pollution, waste remediation, land contamination, water and wastewater treatment were not included in the self-assessment. When questioned by the Evaluation Panel, the response given by the various heads was that this was a decision made by the Ministry of Education. Oddly, the Evaluation Panel was nevertheless given a tour of the Water Chemistry Laboratory, and some presentational material on water-related research at TUT. Moreover, the MSc thesis titles included in the Self-Assessment covered the wider research base in the Department, including water and wastewater treatment, etc. There was no reciprocal comment in the Self-Assessment by the Department of Environmental Engineering concerning the suggestion by the Department of Structural Design to take over the Chair of Heating and Ventilation from Environmental Engineering.

4C.1 Scientific Quality of Research

From 2008 to 2012, the academic and research staff numbers under the Chair of Heating and Ventilation increased from 4 to 10. Grant income rose considerably from 27 thousand €/yr to 384 thousand €/yr across a range of sources. Output publications included 27 journal papers, 8 books or monographs, and 44 proceedings, a rate of about 5, 1, and 8 respective publications per each member of staff over the five-year period—which is in accordance with international norms. However, it should be noted that most of the journal publications were not in top international journals, with a lot in second-tier journals. Two patents were awarded. Achievements stated in the self-assessment relate solely to HVAC and energy efficiency. The Evaluation Panel observed that not all of the items in Achievements section of the Self-Assessment were backed up by evidence (e.g., references to outputs, such as journal publications).

Assessment: The Department of Environmental Engineering is producing research outputs related to civil engineering that are *Good* in the national context, and *Moderate* to *Good* on the international level.

4C.2 Interaction between Research and Society: Public and Professional Activities

The Chair of Heating and Ventilation has been substantially involved in determining Estonian regulations and standards related to building performance and design. The Self-Assessment indicates no weaknesses, but notes a demographic threat in terms of attracting sufficient students given its lack of visibility—this is clearly being tackled by public lectures and schools visits (as evidenced by the Professor of Heat and Ventilation going off to speak to a school on the afternoon of the evaluation visit). Good levels of national and international collaborations are evident.

Assessment: Interaction in the Department of Environmental Engineering between research and society is *Very Good* on the national level and *Moderate* to *Good* on the international level.

4C.3 Research Environment and Organisation of Research

The situation here is complicated. There appears to be a problem concerning the position of Heating and Ventilation. Should it remain within the Department of Environmental Engineering or migrate to a new home in the Department of Structural Design? This appears to be an internal matter, which should be resolved by TUT as soon as possible. The Heating and Ventilation Laboratory's facilities are extensive and located over several sites. The nZEB project is state-of-the-art. The Evaluation Committee valued the productive cooperation between HVAC, Building Physics and Structural Design in the area of nZEB. The Evaluation Panel visited very interesting laboratories dedicated to solar projection and diffuse solar radiation for day lighting. The Evaluation Panel also briefly visited the Water Chemistry Laboratory, which seemed well founded, but is apparently outside the scope of the present evaluation.

Assessment: The research environment with respect to Heating and Ventilation is *Very Good* both nationally and internationally, but the research organisation is partly dysfunctional in the Department of Environmental Engineering.

4C.4 Quality and Relevance of PhD (MSc) Education

3 PhDs were completed in 5 years, 8 are under way. There have been a lot of completed MScs and range of topics is far wider than the self-assessment indicated. There are MScs in water supply, drainage, landfill leakage, sewerage, air quality, pollution, etc., in amongst those on HVAC and energy efficiency. Although these are perhaps strictly outside the brief of the Committee, an argument was made during the interview that the MScs covered environmental matters affecting buildings.

4C.5 Recommendations and Future Potential

Future potential areas of research include building automation and smart buildings, integration of "total" primary energy efficiency of buildings, including the use of renewable energies, environmental impacts and existing building stock. The Evaluation Panel also notes the importance of water engineering in the area of environmental engineering. This should be developed separately; however, it should not be forgotten that water management of buildings is also important. In nZEBs the heating used for domestic hot water may be more than half of the total heating energy used. An important field for the future is the use of biomass as fuel—this area was reasonably well covered in the Estonian University of Life Sciences and should remain there; however, integration into building or area-level systems is needed.

Recommendations:

(1) The Department of Environmental Engineering should continue its productive cooperation with other units in the civil engineering concerning the energy efficiency of buildings.

(2) A strong effort should be made to publish in the top-ranking international journals rather than in second-tier journals.

4D. TUT: Department of Mechanics

4D.1 Scientific Quality of Research

The Department of Mechanics is divided into three Chairs: Fluid Mechanics (covering fluid mechanics, hydraulics, pumps and ventilators and coastal engineering), Technical Mechanics (covering strength of materials, structural mechanics, finite elements, and mechanical vibrations) and Applied Mechanics (covering statics, dynamics, and the theory of elasticity). The Department incorporates a Fluid Mechanics Research Group, a Maritime Engineering Research Group, and a Non-destructive Evaluation and Underwater Acoustics Research Group. From 2008 to 2012, the numbers of academics and research staff increased from ~ 10 to ~ 12. External funding fell slightly from 216 thousand €/yr to 175 thousand €/yr. During this period, published outputs included 38 journal papers, 5 books/monographs, and 49 proceedings, at a rate of about 4, 0.5 and 5 publications per staff—which is in keeping with international norms. Selected research outputs included two joint studies between TUT and Imperial College on crack-induced wave scattering (Ratassepp *et al*., *J. Acoust. Soc. Am.*, 2008 and 2010), a joint paper with Exeter University on leakage management in pipe networks (Puust *et al*., *Urban Water Journal*, 2010), two papers on ship collisions (e.g., Tabri *et al*., *J. Mar. Sci. Technol*., 2010) and transition to turbulence in a pipe (Annus and Koppel, *ASME J. Fluids Engineering*, 2011). Scientific achievements include a fast calibration method for water distribution systems, measurements of air-water interactions in pipelines and unsteady friction losses, a simulation tool for the analysis of maritime accidents, and award-winning publications on resonance at a pipe edge and axial crack detection. Future research directions include internal fluid instability, maritime safety, high resolution test methods for pipes and plated structures, a shallow water acoustic wave model to assess underwater noise by offshore wind farms, and pollution trends in the Baltic.

Assessment: The Department of Mechanics is producing research outputs related to civil engineering that are *Very Good* in the national context, and *Moderate* to *Good* on the international level.

4D.2 Interaction between Research and Society: Public and Professional Activities

Members of staff occupy leading positions in international bodies (e.g., in ISSC, IARS) and have given ETV and Estonian Radio broadcasts (e.g., the documentary *On the top of the Pyramid* and the broadcast on noise pollution in the Baltic Sea). Sensible directions are being taken in terms of national and international research collaborations, in particular the idea of the Blue Green Dream North-Eastern Europe Regional Centre with Imperial College, U.K.

Assessment: Interaction in the Department of Mechanics between research and society is *Very Good* on the national level and *Good* on the international level.

4D.3 Research Environment and Organisation of Research

The Department of Mechanics appears to have a very good team spirit, with new research staff. However, it is still relatively small, and could improve its international visibility. The Evaluation Panel visited the Laboratory of Fluid Mechanics, and observed laser measurements of water particle kinematics under breaking waves in a flume. The laser was effectively unguarded (a potentially major safety issue) and the wave generator comprised a cam-mechanism. The former is a matter for the TUT laboratory safety officer. The latter means that the waves generated are affected by paddle-error waves. This should be overcome by the purchase of a computer-controlled wave generator with (preferably) second-order correction. The Laboratory would benefit from proper risk assessments being carried out, and a general overhaul of equipment. Wisely, the academic staff members have made use of external European facilities through Hydralab III, for example. The Laboratory of Strength of Materials contained standard testing machines for static and dynamic tests, and measurements of the mechanical properties of materials, and a wave propagation measurement facility. This Laboratory was generally in good condition. The Non-destructive evaluation (NDE) and acoustics research group appear to have modern instrumentation and field-test equipment, well-suited to providing acoustic data on the propagation of noise, etc., in the Baltic Sea.

Assessment: The research environment is *Good* nationally and *Rudimentary* to *Good* internationally; the research organisation is *Very Good* in the Department of Mechanics.

4D.4 Quality and Relevance of PhD (MSc) Education

6 PhDs have been completed (one in 3 years), 7 ongoing. One oddity is that two of the PhDs were supervised by Prof. Soomere who is the Head of the Wave Engineering Laboratory, and not counted in the Department of Mechanics. There is a reasonable throughput of MScs: some quick, some slow. The PhD students appear to be well supervised, noting a concern about insufficient attention being paid to risk assessment in the Fluid Mechanics Laboratory. The PhD topics appear well focused. In order to build up the research group, the staff in the Department of Mechanics should attempt to recruit more research students from abroad.

4D.5 Recommendations and Future Potential

The Department of Mechanics could invest more resources to bring its physical test laboratories up to international standard. This is most evident in the Fluid Mechanics Laboratory, where safety risk assessment is also needed.

Important future research opportunities could arise from the maritime accident simulation tools being developed for the Gulf of Finland and the acoustic modelling and monitoring research aimed at understanding underwater noise in the Baltic Sea. Both of these activities could have wide international reach, along with the efforts to understand mixing in stratified flows. Other areas with considerable future potential include ultrasonic NDE of structures for defect detection of composites, unsteady boundary layer flows and waterhammer analysis. Network optimisation and system analysis are very sensible future research directions that are already underway in the Department.

Recommendations:

(1) More investments in up-to-date equipment such as a modern computer-controlled wave generator are needed by the Fluid Mechanics Laboratory.

(2) There should be more collaboration between the Wave Engineering Laboratory and the Department of Mechanics on the physical modelling of waves in shallow water.

(3) Proper laboratory risk assessments should be undertaken.

(4) The laser measurement system in the Fluid Mechanics Laboratory should be made safe using an enclosure.

(5) Effort should be made to recruit more PhD students from abroad.

4E. TUT: Department of Building Production

4E.1 Scientific Quality of Research

This is one of the very few Departments to experience an overall reduction from 14 to 11 academic and research staff from 2008 to 2012. Funding has also fallen slightly from 178 thousand €/yr to 167 thousand €/yr. Published outputs include 8 journal papers, 8 books/monographs and 24 proceedings papers, which equate roughly to 0.7, 0.7 and 2.1 publications per academic over 5 years, which is very low by international standards. Research includes the use of oil shale ash in construction, energy saving, building renovation, evaluation of building products, risk, decision-making, management, energy saving, resilience, etc. Scientific achievements include a Manual of Construction Project Management published by Wiley, work on the durability of oil shale cement concrete, risk transfers and multiskilling related to housing services. There are plenty of plans for future research. While it is unusual to have a Department that combines building materials with construction management and economics, this alignment has arisen for historical reasons. The justification for maintaining this structure is the link based on decision-making affecting managerial strategies and solutions. Such integration is evident in some of the research outputs. The Department perceives that its strengths lie in its expertise and multi-disciplinary nature, but that it has weaknesses regarding its fragmentation, age profile, and heavy teaching load, and the funding being too near-market.

Assessment: The Department of Building Production is producing research outputs related to civil engineering that are *Good* in the national context, and *Moderate* on the international level.

Comment: The Evaluation Panel understands the wish to alter the age profile, but suggests that the undoubted enthusiasm, commitment, and charisma of the senior staff be channelled further towards public understanding.

4E.2 Interaction between Research and Society: Public and Professional Activities

This is demonstrated by the contribution to the Encyclopaedia on Construction Terminology, media interviews, the development of standards for building materials and close links with industry in the areas of construction management economics and real estate management. Good national and international collaborations.

Assessment: Interaction between research and society in the Department of Building Production is *Good* to *Very Good* on the national level and *Moderate* to *Good* on the international level.

4E.3 Research Environment and Organisation of Research

The Department hosts the Testing Laboratory of Building Materials (founded in 1956). During the site visit, the Committee was very impressed with the great enthusiasm of the staff, inspirational leadership, and considerable pride shown in the facilities.

Assessment: The research environment in the Department of Building Production is *Very Good* in the Estonian context, and the organisation of research appears to be *Very Good*. This would translate to *Good* internationally.

4E.4 Quality and Relevance of PhD (MSc) Education

Only two PhDs have been completed in 5 years (one has taken 11 years, the other 5.5 years). A large number of MScs have been completed, but a notable feature has been the fact that almost half of them have been in the area of in Building Site Management. This reflects the strengths of the supervision team but indicates a lack of variety in subject area.

It should be noted that the setting-up of a CIB Student Chapter would be an important step in developing a meaningful doctoral school in the sense of an active community. Interaction through virtual workshops, etc., with other groups of doctoral students in the top Construction Schools throughout the world would add a strong international dimension. CIB (International Council for Research and Innovation in Building and Construction) is the world's leading organization in this research field and TUT is already a member, with several academic staff playing very active roles.

4E.5 Recommendations and Future Potential

Staff in the Department of Building Production has great potential to develop further their international collaborative activity in specific niche areas. They are already partners in European projects such as CADRE (Collaborative Action towards Disaster Resilience Education), concerned with developing and testing an innovative professional doctoral programme that integrates professional and academic knowledge in the construction industry, and in the ANDROID disaster resilience project with the UNISDR. Further development of such links can raise the international profile of the Department and lead to more funding opportunities.

The experience the Chair of Building Materials has gained concerning the substitution of Portland clinker by shale oil ashes offers an excellent research opportunity for incorporating other cementitious by-products, which is a major worldwide trend.

Recommendations:

(1) The Department should seek ways of rationalising its very heavy teaching load (reported as about 6,000 hours per annum shared between 9 members of staff)

(2) The Department should place more emphasis on publishing its research findings in peer-reviewed international journals.

(3) A new Professor of Building Materials should be appointed. Obviously, this field plays a central role in civil engineering faculties. Many contemporary challenges concerning structural safety and energy use are essentially materially related.

(4) The Testing Laboratory is accredited for standard testing for a large number of building materials and has particular expertise in the use of burnt oil shale for cement production and in the testing of aggregates, but the research infrastructure of the Building Materials laboratory should be re-evaluated to enable the unit to reach its potential to provide a useful facility for the industry in terms of future refurbishment and operation of the building stock.

4F. TUT: Departments of Road Engineering, and Logistics and Transport

4F.1 Scientific Quality of Research

This Department of Road Engineering covers road and bridge engineering and engineering survey (geodesy). The Department of Logistics and Transport (established Feb. 1st, 2012) covers transport planning, transport logistics, and supply chain engineering. Research activities of the Department of Road Engineering are concerned with roads, bridges, traffic safety, transport, and surveying (geodesy). From 2008 to 2012 the number of academic and researcher staff of the Department of Road Engineering decreased from 16 to 13. External funding increased threefold from 192 thousand €/yr to 600 thousand €/yr, mainly from national research and development sources, other public financing, and some EU funds. Outputs include 42 journal papers, 4 books/monographs, 53 proceedings corresponding to about 4, 0.4 and 5 publications per member of staff over the evaluation period, which is in line with international norms. The Laboratory of Roads and Traffic have mainly performed consultancy and laboratory testing while Geodesy also

had funding from the Estonian Research Council and the Archimedes Foundation for the geodetic research.

The self-assessment states a large number of possible scientific achievements, without identifying the five best. The stated achievements include important national contributions to modelling strength of pavements, enhancement of the Estonian pavement design guide, updating of road research standards, research on road maintenance and materials, condition of bridge joints, assessment of bearing capacity of bridges, modelling traffic flows, improved geoid and gravity field models regarding the Baltic Sea, and a height reference frame of the Estonian coastal waters. Also, traffic safety and collaboration with EU research have been important national research areas.

Future road research will comply with the national road development strategy for the development of sustainable and safe transport corridors to support economy and protect the environment. Estonian Road Administration is planning to determine a long-term research plan in the near future, which will set the directions of road and traffic related research. In Geodesy BIM, airborne lidar detection for coastal processes, remote sensing, configurations of inaccessible parts of buildings, calibration and certification of geodetic instruments are among areas of future interest, likewise, domestic and international research cooperation on GIA modelling. For a small country such as Estonia, it is important to recognise its strengths and to collaborate in areas where there are less resources. Rail Baltic high-speed railway development is an area where collaboration would be beneficial.

Assessment: The Department of Road Engineering and Department of Logistics and Transport are producing research outputs related to civil engineering that are *Good* to *Very Good* in the national context, and *Moderate* to *Good* on the international level.

4F.2 Interaction between Research and Society: Public and Professional Activities

Membership of technical committees and professional associations (e.g., Technical Committee of Roads of the Estonian Centre of Standardization, Estonian Asphalt Pavement Association, Estonian Logistics Cluster, Estonian Waste Recycling Cluster) which participate in the important national work of unifying standards, renewing design procedures and specifications and monitoring infrastructure during construction. Interaction also includes the provision of expertise to the Estonian Qualifications Authority, CPD refresher courses, and training courses for traffic safety auditors. Frequent guest appearances on TV shows on public safety hazards and construction delays on roads. International collaboration aims towards geodetic infrastructure. The Geodesy Group is participating in international European research networks and collaborating with neighbouring countries and Canada. Participation in a range of Baltic and EU activities, such as publishing the joint scientific *Journal of Road and Bridge Engineering* with the Baltic countries.

Assessment: Interaction between research and society in the Department of Road Engineering and Department of Logistics and Transport is *Good* to *Very Good* on the national level and *Moderate* to *Good* on the international level.

4F.3 Research Environment and Organisation of Research

The Evaluation Panel visited the GIS and geodetics laboratories, which appeared to be well-founded and in a modern, research-friendly space. The Pavement Engineering Laboratory was equipped with modest, traditional, basic material testing facilities. The Bridge Engineering Laboratory was spacious, with the small-scale bridge model providing a good hands-on learning tool for students.

Assessment: The research environment in the Department of Road Engineering and the Department of Logistics and Transport is *Moderate* to *Good* in the national context and *Moderate* internationally.

4F.4 Quality and Relevance of PhD (MSc) Education

Two PhDs and a large number of MScs were completed during the 5-year evaluation period. 19 PhDs are ongoing. One-third of the students are in the early- and mid-stages of research and systematic supervision is important to get them through within the targeted time frame. Another one-third is well beyond the targeted time frame and finding ways of helping them to graduate is important. Most of the students are carrying out research in the logistic and geodesy areas, and alarmingly few are working in the road engineering and materials areas. There are active student and professor exchanges with other Baltic universities, Germany, Sweden and Finland. The interview with students revealed that they are funded to attend international conferences, and network. It is important to keep the young ambitious PhD students motivated and create appreciation for higher education in the construction job market and within industry, as not all postgraduates can find positions in the academia.

4F.5 Recommendations and Future Potential

Recommendations:

(1) A competence centre for road/bridge/transport related research should be established to create critical mass and coordinate research activities and future EU research projects.

(2) Meanwhile, the Department of Logistics and Transport should continue its road-related research activities with TTK UAS and its geodesy activities with the Estonian University of Life Sciences.

(3) The Department of Logistics and Transport should coordinate its new activities with already established groups in Estonia and improve its international collaborations.

(4) PhD output should be increased; a more structured doctoral program would be beneficial with joint on-line courses with universities in neighbouring countries.

(5) The Departments should seek collaboration in the new Horizon20/20 EU framework program to increase PhD students' salaries, particularly in focused research topics such as road materials and recycling.

(6) Introducing road and transport engineering for high-school students to create interest and recruit new students would be beneficial.

4G. TUT: Department of Landscape Architecture (in Tartu College)

4G.1 Scientific Quality of Research

Over the period from 2008 to 2012, the number of academics in the Department of Landscape Architecture rose from 8 to 11. External income has risen substantially from 37 thousand €/yr to 319 thousand €/yr, partly from EU sources, mainly from Estonian research contracts. The stated published output includes 31 journal articles, 2 books/monographs, and 30 proceedings papers. However, this did not accord with the evidence supplied on the CVs, with regard to the area of research the Panel was asked to evaluate. As a result, the Panel is unable to give a view regarding the national or international quality of the research. The main scientific achievements include the first edition of *Acta Architecturae Naturalis* and the Estonian Landscape Architecture Award 2011. Future research activities will be directed towards expansion beyond Estonia through enhanced international collaborations, raising the profiles of the staff based on well-founded infrastructure. The Department has developed productive international connections with universities in the United States and Europe.

Assessment: The Evaluation Panel was unable to assess the quality of civil engineering related research in the Department of Landscape Architecture due to insufficient evidence owing to the classification system.

4G.2 Interaction between Research and Society: Public and Professional Activities

The Department of Landscape Architecture is involved in national bodies (e.g., membership of the Heritage Conservation Panel). The Department carries out international study-abroad exchange programmes with institutions in the U.S. and Romania, and a joint workshop with Lisbon Technical University.

Assessment: Interaction between research and society in the Department of Landscape Architecture appears to be *Good* on the national level and *Good* on the international level.

4G.3 Research Environment and Organisation of Research

This is a satellite Department with a certain amount of budget autonomy. The impression is that the Department is lively and enthusiastic, but feels rather remote from the decision making in Tallinn.

Assessment: The Evaluation Panel was not invited to visit the Department of Landscape Architecture, and so has not provided an assessment due to a lack of *in situ* information.

4G.4 Quality and Relevance of PhD (MSc) Education

From 2008 to 2012, no PhDs were completed in the Department of Landscape Architecture. There are currently 3 ongoing PhDs. However, 28 MScs did complete successfully during the evaluation period. Beyond this, the Evaluation Committee did not have enough information to comment further about the quality and relevance of graduate-level education in this Department.

4G.5 Recommendations and Future Potential

The Department of Landscape Architecture has the potential to carry out useful research broadly related to the sustainability and heritage of rural architecture. The Department is making strong efforts to increase its international exchange activity which is commendable, but there is a need for all the academic staff to complete PhD studies and produce peer-reviewed outputs in top journals.

Given the small size of Estonia, the subject of landscape architecture seems quite dispersed/scattered over 4 institutions at least. It merits the effort to explore the possibilities of rationalising the offering in this area, and get rid of historically grown structures: one track could be that urban studies are offered/studied in Tallinn (EAA and TUT) and rural subjects in Tartu (i.e., at TUT Tartu College, the Estonian University of Life Sciences and the University of Tartu). *Idem ditto* for the study of heritage of architecture and urbanism in Tallinn and rural constructions in Tartu.

Recommendations:

(1) All academic staff should be incentivised to complete a PhD.

(2) TUT landscape architecture in Tartu College should collaborate (and maybe 'fuse') with EMÜ.

4H TUT: Wave Engineering Laboratory

4H.1 Scientific Quality of Research

The Wave Engineering Laboratory is located within the Centre of Non-Linear Studies (an Estonian Centre of Excellence 2011–15). Its research is predominantly concerned with wave and marine engineering, in particular non-linear phenomena in wave dynamics and coastal engineering, wave loading, sediment transport, integrated zone management, and maritime spatial planning. Its major scientific achievements include determining the main properties of the Baltic Sea wave climate, the fundamentals of long wave dynamics, rogue waves, wave-driven sediment transport, and predictions of coastal environmental processes and fairway design. One researcher was awarded the very prestigious Plinius Medal of the European Geosciences Union. Researchers in the Wave Engineering Laboratory have also received several national awards. From 2008 to 2012, the number of research staff in the Wave Engineering Laboratory has increased from 5 to 7, of whom 4 are Senior Scientists. Research funding has increased from 110 thousand €/yr to 264 thousand €/yr from a variety of sources, including the Estonian Science Foundation. Published output includes 115 journal papers, 1 book/monograph and 55 articles in proceedings, a prolific rate of about 20 journal publications per researcher in 5 years, at an internationally leading level. Research is conducted predominantly in wave and coastal engineering. The research

group appears to be highly focused on long waves, marine and coastal hazards, and the changing wave climate. The outputs made available to the Evaluation Panel indicate that the group is making major contributions to our knowledge of offshore and coastal processes, and working collaboratively with other internationally leading researchers at institutions in Australia, Finland, France, Russia, etc. The work is particularly strong in the areas of analytical wave mechanics (e.g., Didenkulova *et al*., *JGR*, 2009), the statistics of rogue waves (Nikolkina and Didenkulova, *Natural Hazards and Earth System Sciences*, 2011) the simulation of physical oceanographical processes (e.g., Soomere *et al*., *Oceanologia*, 2008), and the optimisation of marine fairways (Soomere *et al*., *Mar. Pollut. Bull*. 2011).

Assessment: The Wave Engineering Laboratory is producing research outputs related to civil engineering that are *Excellent* on the international level.

4H.2 Interaction between Research and Society: Public and Professional Activities

Interaction includes the editorship of an international journal (*Natural Hazards & Earth Systems*) and membership in editorial boards (*Scientific World Journal*, *Journal of Marine Systems*, *Oceanologia*), summer school on coastal protection, keynote lectures, and popularisation of science. A series of popular lectures on rogue waves was delivered in Lithuania, for example. Staff members in the Wave Engineering Laboratory were awarded prizes for TUT Scientist of the Year in 2011 and for the Best Popularisation of Science in Estonia in 2011. Receiving the Plinius medal of the European Geosciences Union is a measure of international excellence with regard to the professional activities.

Assessment: Interaction between research and society in the Wave Engineering Laboratory is *Excellent* on both the national and international level.

4H.3 Research Environment and Organisation of Research

Although the Evaluation Panel did not visit the Wave Engineering Laboratory, the self-assessment and presentation (along with the undoubted high quality of the outputs) indicate that the research environment and organisation is first class. The Wave Engineering Laboratory matches the definition of a Centre of Excellence.

Assessment: The research environment and organisation of research appear to be *Excellent* in the Wave Engineering Laboratory.

4H.4 Quality and Relevance of PhD (MSc) Education

From 2008 to 2012, 6 PhDs and 2MScs were completed by candidates in the Wave Engineering Laboratory working in the area of Civil and Environmental Engineering. There are 8 ongoing PhD students. It should be noted that the Wave Engineering Laboratory also encompasses PhDs and MScs in Natural and Exact Sciences and Earth Sciences. It is obvious from the outputs that the graduate students in the Wave Engineering Laboratory are very well supervised by internationally leading experts in the field.

4H.5 Recommendations and Future Potential

The Wave Engineering Laboratory aims to continue its research efforts in wave dynamics, coastal processes, and coastal engineering and management. The future directions outlined in the self-assessment are all scientifically at a very high level. The Wave Engineering Laboratory identifies additional future opportunities in creating a pan-Baltic Centre on Coastal and Environmental Engineering. There are future potentials to be exploited with regard to oceanographic and coastal data concerning the Baltic Sea, and possibly transformative breakthroughs are to be made in our understanding of wave mechanics. A risk that must be faced by TUT is the potential loss of key staff to research-intensive universities abroad where higher salaries may be offered.

Commendation: The Evaluation Panel commends the output of research produced by the Wave Engineering Laboratory, and suggests that TUT investigates means by which to avoid possible staff retention problems.

5. University of Tartu

5.1 Scientific Quality of Research

The University of Tartu does not have any engineering or architecture departments or faculties, although there are R & D activities regarding the environmental impact of buildings. Research is aimed at energy efficiency and low carbon emissions. Civil engineering related research at the University of Tartu, therefore, focuses primarily on the general area of energy performance of buildings, and secondly on urban and landscape planning. The energy efficient building core laboratory was established in April 2006 but no scientific papers were published by 2013 (according to the CVs of the personnel the committee met at the University). The CVs reported only three published conference papers, and one conference paper to be published in 2013 in the area of energy efficiency. According to the self-assessment, the number of research-active staff working in these areas has increased from 11 in 2008 to 12 in 2012. Research funding per annum has fallen from 356 thousand €/yr to 259 thousand €/yr over the past 5 years (though this looks like a blip, given that the funding in 2011 was 866 thousand €/yr). In the self-assessment, the stated research output includes 119 journal articles, 0 books/monographs, and 72 articles in proceedings. The Evaluation Panel examined some of these outputs and concluded that only a few of the research outputs reported fell within the civil engineering areas that the panel was supposed to evaluate. [The Evaluation Panel is aware that the majority of personnel put forward as research-active staff conduct research in multiple fields, of which civil engineering is often a minor aspect, especially with regard to the topics related to spatial planning. Moreover, the research-related staff submitted only research outputs related to civil engineering–taken in its broadest sense.] The Evaluation Panel met a subset of the academic and research staff.

Assessment: The University of Tartu is undertaking basic research that appears to be of a high quality (such as in the field of general material sciences), but not in the area of traditional civil engineering.

5.2 Interaction between Research and Society: Public and Professional Activities

Assessment: The Evaluation Panel was not provided with sufficient information during the visit to give a proper assessment of the interaction between research and society at the University of Tartu. The results directly related to civil engineering in the self-assessment appear to be modest or do not exist. The Panel believes that it would be a waste of resources for the Estonian government to support nZEB research in two universities unless the aim is to stimulate competition: i.e., which university reaches zero energy sooner or more cost-effectively.

5.3 Research Environment and Organisation of Research

The University of Tartu appears to have a very supportive senior management structure that encourages academic freedom and interdisciplinary collaboration. The senior management is working hard to promote international collaboration, and engenders a sense of pride concerning the university's long and distinguished history. There are well-established national collaborations with Tallinn Technical University and Kodumaja AS. The Evaluation Panel was not given a tour of the facilities (which supposedly comprise of office rooms where computer simulations take place), and so it is not possible to comment on the physical research environment other than to note that the university appears to have a dynamic building simulation capability, and CFD tools. The University of Tartu operates a model of individual, self-organising R & D groups, but will provide help for coordinated research.

Assessment: The Evaluation Panel is unable to give an accurate assessment of the research environment and the organisation of research related to civil engineering at the University of Tartu.

5.4 Quality and Relevance of PhD (MSc) Education

The University of Tartu has more than 1,500 PhD students and awards nearly 100 PhDs yearly. The panel was confronted with discrepancies between figures reported of PhD students in the civil engineering ETIS system and those reported on site. ETIS shows 1 PhD defended and 2 studying in the period under assessment. In 2011 and 2012 there were no students in the University of Tartu doctoral programme titled "Environmental Protection" (8 in 2008; 5 in 2009; 2 in 2010). During the visit, more than 20 PhD students were reported. [This is because few PhD students are working in areas directly related to 'civil engineering' as defined according to the existing CERCS category; however there are other students at the University of Tartu who are not counted within this category but fit a broader definition of civil engineering.] PhD students are represented in the University Senate and the Faculty Council.

5.5 Recommendations and Future Potential

The University of Tartu should continue its high level basic research in material sciences and other civil engineering-related areas in close cooperation with TUT. The cooperation could create innovation and applications for better buildings. The University of Tartu could, for example, develop mathematical models for physical phenomena that are relevant for further application in civil engineering. The University of Tartu should not invest resources in applied civil engineering research, and should not start offering engineering degrees. Its future potential is in basic research and the possible integration of various faculty members in a multi-disciplinary research team.

6. Estonian University of Life Sciences

The Evaluation Panel was impressed with the courteous reception, extensive tour and well-prepared documentation it received at The Estonian University of Life Sciences.

6.1 Scientific Quality of Research

The Estonian University of Life Sciences (EMÜ) is located in Tartu. It carries out research in the range of civil engineering and related subjects, including rural construction, geodesy, landscape architecture, energy engineering (HVAC) and rural economics (construction economics). This research is carried out in three departments: Department of Rural Building (research in thermal properties of insulation materials, investigation of existing concrete and timber structures, and building physics in the context of agricultural buildings); Department of Geomatics (research into geodesy, gravimetry & photogrammetry, land-use planning, land management); and Department of Landscape Architecture (research into future landscape development, led by a recently appointed international professorial HoD). The research specifically serves rural areas, where the use of renewable materials for buildings and renewable sources of energy has an important role to play. In particular, research into the use of wood and other biomass as fuel in energy production has been developed, and research facilities have been established. Moreover, the research on wooden houses supports the Estonian export industry. Taking into account the huge forest resource in Estonia, the use of wood in various forms as fuel is important. The number of academic staff in these departments increased from 43 in 2008 to 48 in 2012. Research funding per annum increased from 209 thousand €/yr to 326 thousand €/yr over the evaluation period. Research output includes 118 journal articles, 10 books/monographs, and 192 articles in proceedings. This equates about 3 journal papers, 0.25 books/monographs, and 5 articles in proceedings per member of staff over the 5-year period. Scientific achievements listed in the self-assessment include the production of a Compendium on the Mechanical and Insulating Properties of Local Materials (as part of INTERREG IV); a visual assessment method applied to agricultural buildings + corrosion; reconstruction of the Estonian levelling network; the use of space technologies to improve geoid and gravity field models over Estonia; and the correction and calibration of airborne laser scanning (ALS) intensity data. In the future, the Estonian University of Life Sciences (EMÜ) intends to focus on the sustainable use of renewable natural resources, as well as land-use planning and factors affecting land-use. The Department of Rural Building will continue to investigate thermal properties of local insulation materials and propose optimal solutions for local climate conditions; new concrete and timber structures; and investigation into sustainable construction of agricultural buildings. The Department of Geomatics will calculate a more accurate geoid model and calibrate satellite altimetry data for the coastal areas of Estonia and its islands. The Department of Landscape Architecture will continue to develop the field of relationships between people and landscapes in urban and rural areas. From the Institutional perspective, the Estonian University of Life Sciences aims to increase the number of personnel with PhD degrees, intensify research activity, and complete (in terms of equipment) a new Laboratory of Building Structures. A new digital gravimeter is presently being purchased. The Evaluation Panel believes that EMÜ is well positioned to address the future challenge of a greener society. The academic and research staff appear to be well-motivated and have multi-disciplinary expertise, and are supported by the university. From the self-assessment and the meeting with the staff and students, it would appear that there is a very good awareness of EMÜ's strengths,

weaknesses, opportunities and threats, and a good idea of how to move forward. The Evaluation Panel agrees with EMÜ in that there are many opportunities to collaborate with partners abroad with a similar profile, including in networking and joint research. EMÜ has identified future areas in renewable materials, remote sensing, land-use planning, geodetics and surveying that will play to its strengths as a university, and also meet the objectives of Estonian society.

Assessment: The Estonian University of Life Sciences is producing civil engineering research outputs that are *Good* to *Excellent* in the national context, and *Moderate* to *Good* on the international level.

6.2 Interaction between Research and Society: Public and Professional Activities

Interactions between research and society at the Estonian University of Life Sciences include close collaborations with Kodumaja AS and AS TMB, awards from the Estonian Concrete Society, and memberships of qualifications and standards boards. The Estonian University of Life Sciences has hosted seminars and workshops in Estonia and Finland as part of ProNatMat. The Head of the Department of Landscape Architecture has been elected President of European Council of Landscape Architecture Schools.

Assessment: Interaction between research and society at the Estonian University of Life Sciences is *Very Good* in certain areas both in the national and international context.

6.3 Research Environment and Organisation of Research

From the tour and self-assessment, the Evaluation Panel gained an impression that the facilities at EMÜ range from *Moderate* to *Very Good*. The university appears to have extensive collaborations with other Estonian universities, Estonian government agencies, and international partners. PhD students are represented in the Faculty Council and University Senate. The Laboratory facilities vary considerably in quality, with some of the older laboratories needing investment (which appears to be on-going), and others being close to state-of-the-art. The University provides a supportive research environment which is conducive to good research. The Evaluation Panel noted the generally good morale of staff and students encountered during the visit.

Assessment: The research environment at EMÜ ranges from *Moderate* to *Good* and the research organisation is *Very Good* in the national context.

6.4 Quality and Relevance of PhD (MSc) Education

4 PhDs were awarded in the area of civil engineering during 2008–2012 in EMÜ. EMÜ has 2 doctoral education programmes: Environmental Sciences and Applied Building Sciences (60 students in 2012) and Engineering Sciences (with 32 students in 2012). A PhD study curriculum counts 60 ECTS for doctoral studies and 180 ECTS for the PhD thesis.

The Evaluation Panel was provided with examples of PhD and MSc theses and met with a subset of students. From a sample of several MSc theses it was evident that there was a lack of proper referencing to published material in international journals. The research quality appeared to be *Moderate*, being rather broad and shallow. The students appeared very satisfied with their experience at EMÜ, though they expressed a wish for co-supervision to be uniformly required. In general, the frequency and quality of supervision appeared to be *Very Good*.

Assessment: The quality and relevance of PhD (MSc) Education at EMÜ is *Moderate*.

6.5 Recommendations and Future Potential

The Estonian University of Life Sciences should continue to conduct research into rural buildings and infrastructure, the effective use of natural resources, cost-effective use of renewable energy sources, reduction in environmental impact, and the indoor environment and energy efficiency of farm buildings

Major Recommendations:

(1) Close collaboration with colleagues at other universities in Tartu should be compulsory.
(2) By testing materials and building elements for the local or neighbouring markets, EMÜ is profiling itself as a very local/national institution. To have wider reach, EMÜ must aim at creative research of international interest and develop tools that enable the progress of engineering science, more than merely use existing tools.

(3) The Panel would welcome a nationwide unification/rationalisation effort in order to reduce the scattering of subjects over too many institutions. This recommendation transcends EMÜ as such and refers to all institutions visited.

Minor Recommendations:

(1) EMÜ should encourage its students to undertake formal literature reviews in English that encompass international journal publications—as a step towards achieving a higher international rating in research quality (which is within reach).

(2) PhD and MSc students should be required to write a summary in English, and include a comprehensive literature review in their theses.

Appendicies

Appendix 1. ANNEX II TO THE CONTRACT FOR SERVICES

Ministry of Education and Research
Directive of the Minister (non-official translation)
Tartu *12 July 2013 No. 337*

Approval of subject, participants, personnel and detailed organisation of the 2013 targeted evaluation of research in civil engineering

On the basis of Subsection 20^2(3) of the Organisation of Research and Development Act:

1. To organise the 2013 targeted evaluation in the field of research on civil engineering, sub-field of natural sciences and engineering field (hereinafter evaluation).

2. I assign research in civil engineering and related fields as the subject of the evaluation:

    - Structural engineering, including building materials, general building
    - Mechanics and marine engineering
    - Construction economics and management
    - HVAC, indoor climate, energy performance and building physics
    - Road engineering, transport and geodesy
    - Architecture, urban planning and landscape architecture.

3. I assign the following institutions as participants in the evaluation:

    - Estonian University of Life Sciences
    - Tallinn University of Technology
    - University of Tartu
    - Estonian Academy of Arts
    - TTK University of Applied Sciences.

4. I appoint the following people as members of the international panel (hereinafter evaluation panel) responsible for carrying out the evaluation:

    - Alistair Borthwick, professor at University College Cork, panel chairman
    - Olli Seppänen, professor emeritus at Aalto University
    - Herman Neuckermans, professor emeritus at KU Leuven
    - Jos Brouwers, professor at *Eindhoven University of Technology*
    - Les Ruddock, professor at University of Salford
    - Terhi Pellinen, professor at Aalto University.

5. I approve the detailed procedure for executing the evaluation (appended).

6. This directive may be challenged within 30 days of publication by filing a complaint with the Tartu Administrative Court in accordance with the Code of Administrative Court Procedure.

/*Signature*/

Jaak Aaviksoo

Minister

To be issued to: participants in the evaluation, Research Department of the Ministry of Education and Research, Estonian Research Council, persons specified in the Minister of Education and Research directive No. 168 from 19 April 2013 “Formation of committee for preparing the 2013 targeted evaluation of research in civil engineering”.

Annex
APPROVED
by Minister of Education and Research directive No. 337 from 12 July 2013

Detailed procedure for performing the evaluation

1. The evaluation is carried out to provide information on research in civil engineering and the level, productiveness and influence of research fields related to civil engineering to the research community, research and development institutions, research funding organisations, research policy planners and society at large. The results of the evaluation serve as an input for preparing research policy decisions and measures pertaining to research in civil engineering and related fields, further development of the field, preparation of development plans and introduction of necessary changes.

2. Before assuming their positions the members of the evaluation panel carrying out the evaluation shall sign a declaration of independence and confidentiality in a format approved by the authority organising the evaluation, and also undertake not to use or disclose to third parties any public or non-public information, such as data, documents and other information they learned or to which they were referred in the course of the evaluation after the end of the evaluation process.

3. For carrying out the evaluation, the institutions participating in the evaluation shall submit, through the corresponding environment of the Estonian Research Information System, by 15 October 2013:

   - a self-evaluation report (including general information on the institution, overview of research and development activities, self-evaluation, overview of cooperation and activities aimed at the public) in a format approved and published by the institution carrying out the evaluation

   - data which serve as a basis for the evaluation (including information on personnel, research results, doctorate studies, infrastructure, research projects and financing).

4. The evaluation panel retains the right to:

   - receive additional information necessary for the evaluation from participants in the evaluation, the authority organising the evaluation, and the committee preparing the evaluation, formed on the basis of the Minister of Education and Research directive No. 168 of 19 April 2013, “Formation of the committee for preparing the 2013 targeted evaluation of research in civil engineering” (hereinafter Steering Group)

   - visit the institutions participating in the evaluation for the purpose of obtaining additional information necessary for evaluation, providing at least 10 working days advance notice.

5. Based on the information specified in clauses 3 and 4 of this directive’s annex the evaluation panel shall analyse the quality of research studies in the field of civil engineering, the research environment and organisational structure of the institutions participating in the evaluation, as well as the public influence and pertinence of their research and development activities related to civil engineering.

6. The evaluation panel may use meetings or other formats as a working format pursuant to the decision of the evaluation panel and involve experts who possess the information necessary for carrying out the evaluation, if necessary.

7. As a result of the analysis specified in clause 5 of this directive's annex the evaluation panel shall compile a report on the target evaluation of research in civil engineering in the extent specified in clause 1 of this directive, i.e., in the report, the panel shall:

    1. evaluate the quality of research in the sub-field of civil engineering (hereinafter field) in Estonia compared to the international level, including:

        - identify, evaluate and analyse the strengths and weaknesses of the research and development activities in the field in institutions evaluated and in Estonia generally

        - assess the output and quality of the performed research

        - assess the collaboration with key academic partners at home and abroad

    2. evaluate the public and professional activities undertaken in the field by institutions evaluated, including:

        - assess the links between research and development, and the requirements of industry and different policies

        - assess the collaboration with key stakeholders in the Estonian society

    3. assess the organisation of research in the institutions evaluated, including:

        - assess the organisation of research in the field by the state and the links between the research and national strategies as well as development plans

        - assess the general organisation of research in the institution and the links between the research and institutional as well as national strategies and development plans

        - assess the condition of the infrastructure of an institution for the purpose of guaranteeing the sustainable development of research

    4. assess the quality and relevance of the doctoral (if relevant) and Master's studies in the field, including:

        - assess the quality and volume of doctoral studies compared to the international level based on the need to ensure the sustainability of research and development

        - assess the links between doctoral studies with research and societal needs

        - assess the supervision and level of efficiency of doctoral studies

        - assess the volume of Master's studies and links between studies with research and societal needs

5. assess the future potential of the institution evaluated

6. give recommendations and make proposals with regard to the further development and financing of research and development activities in the field and the performance of necessary changes in Estonia, including providing suggestions and recommendations:

   - for the further development of research policy in Estonia

   - for the further development of research in institutions evaluated

   - for ensuring the further sustainable development of research and development in the field.

8. In their assessments the evaluation panel shall take into account the following specific topics and conditions throughout all the subsections of the field:

   1. energy efficiency, simulations, BIM, green building and human wellbeing are general growth trends both in Estonia and abroad. Innovative construction and "smart" buildings are determined as one priority growth area in the new Estonian strategy of RD&I. Does the research carried out in Estonia as well as the future plans and opportunities of institutions evaluated support those trends and corresponding research?

   2. What are the deficiencies of the research carried out in the field? Are there sub-fields relevant for Estonia that do not receive the necessary attention? Are there unsubstantiated overlaps in research that may indicate the inefficient use of resources?

9. The evaluation panel shall submit the evaluation report and other materials compiled during the activity of the evaluation panel to the authority organising the evaluation by 1 February 2014.

10. The authority organising the evaluation shall forward the report to the Steering Group for an opinion. The Steering Group shall submit its opinion on the evaluation report to the authority organising the evaluation within 10 working days.

11. The authority organising the evaluation shall forward the evaluation report with the opinion of the Steering Group to the Ministry of Education and Research and to the Ministry of Economic Affairs and Communications within 5 working days. The authority organising the evaluation shall organise a public presentation and further discussion of the evaluation report as well as the compilation of an action plan in cooperation with the aforementioned Ministries.

/Signature/
Taivo Raud
Vice head of department of research policy
in the capacity of department head

Appendix 2. Evaluation panel members

Professor Alistair Borthwick, chairman of the panel
Alistair Borthwick is Professor and Chair in Applied Hydrodynamics at the University of Edinburgh, UK. He is also an Emeritus Fellow at St Edmund Hall, Oxford, and Adjunct Professor at Peking University.
Professor Borthwick was previously Professor of Civil and Environmental Engineering at University College Cork, Ireland and Professor of Engineering Science at the University of Oxford.
He has more than 35 years' experience in civil, coastal and offshore engineering and was a member of the design team of the Hutton Tension Leg Platform, which won the Queen's Award for Technological Achievement in 1984. He was Chairman of the UK Coastal Research Facility from 1996 to 2004.
Professor Borthwick's research interests include shallow water-sediment flows, flood risk, coastal processes, offshore engineering and marine and renewable energy. He has co-authored more than 120 papers in peer-reviewed journals, and supervised 36 doctoral students to completion.
Professor Borthwick is a Fellow of the Institution of Civil Engineers, and in 2007 was awarded a DSc by the University of Oxford.

Professor Jos Brouwers
Jos Brouwers is Professor in the Department of the Built Environment in Eindhoven University of Technology, Netherlands. He is also a guest professor in Wuhan University of Technology, China.
Professor Brouwers defended his PhD in 1990 with topic „Film models for transport phenomena with fog formation, with application to plastic heat exchangers and condensers".
His research interests include sustainable and functional construction materials and buildings; granular mix design and concrete/mortar rheology; microstructure and pore water chemistry of hydrating cement/lime/gypsum and cementitious by-products. Professor Brouwers is author of 2 books and more than 100 papers in peer-reviewed journals and 30 professional publications, and supervised 6 doctoral students to completion.
Since 2013 he is editorial board member of *Vestnik*, a peer-reviewed journal published by the Moscow State University of Civil Engineering.

Professor Emeritus Herman Neuckermans
Herman Neuckermans is Emeritus Full Professor at KU Leuven, Belgium. He graduated as an engineer-architect, went in practice and obtained his PhD in 1976 with a subject on Design methodology in architectural design - Computer aided Architectural Design. He has served as Head of Department of Architecture, Urban design and Physical Planning at KU Leuven for 30 years.
His research domain includes design methods and theory, in particular CAAD and computer aided architectural design in the early stages of design.
He has been president of the European Association for Architectural Education (EAAE) from 2000 till 2003 and has been chair/member of many international research and education assessment committees.
He is author of more than 140 scientific papers, and has supervised 16 doctoral students to completion.

Professor Terhi Pellinen

Terhi Pellinen is Professor of Highway Engineering at Aalto University, Finland. She received her PhD in Civil Engineering in 2001 from Arizona State University, USA.

Professor Pellinen worked for 12 years in industrial environment both in Europe and in the USA. She was the Head of the Highway Laboratory Section at the Technical Research Centre of Finland, VTT. In USA, she was acting as Chief Engineer and Engineer in charge for 3 years at Advanced Asphalt Technologies, USA.

Professor Pellinen is a head of M.Sc. Study Program of Department of Civil and Environmental Engineering at Aalto University. She has supervised 3 PhD theses and has served as an expert evaluator at different international units.

She is a member of the Association of Finnish Civil Engineers, member of ASCE American Society of Civil Engineers, member of the European Federation of National Engineering Associations. Professor Pellinen is a member of the Editorial Board of the *International Journal of Road Materials and Pavement Design* and has been member of the scientific committee and referee for several international conferences.

Professor Pellinen authored more than 110 scientific publications and technical reports.

Professor Les Ruddock

Professor Les Ruddock is the Chair of Construction and Property Economics at the University of Salford, UK. He received his PhD in economics in 1993. He is also a Board Member of the *International Council for Research and Innovation in Building and Construction (CIB*) and is Director of the Working Commission on Construction Industry Economics.

His research interests include construction industry economics – macroeconomic, mesoeconomic and microeconomic applications; and environmental economics.

Professor Ruddock is the author over one hundred scientific and professional publications.

Professor Emeritus Olli Seppänen

Professor Olli Seppänen is the editor-in-chief the REHVA European Journal of Heating, Ventilating and Air-conditioning Technology since 2008. He was Secretary General of Federation of European Heating, Ventilation and Air-conditioning Associations 2008-2012 and the president from 2005 to 2008.

He served as professor and head of the Institute for Heating, Ventilating and Air Conditioning at Helsinki University of Technology, Finland, 1982-2008. He has worked for over 25 years in the research of energy performance of buildings and indoor environment. He has authored five university level text books related to energy performance of buildings, and published more than 300 scientific and technical papers. He has evaluated several international and national research programs and he is a member of the editorial board of several scientific journals. Olli Seppänen has worked also in the USA as a consult and a scientist at Kansas State University and Lawrence Berkeley National Laboratory, CA.

Olli Seppänen is a founding member of international scientific organisation International Society of Indoor Air Quality and Climate (ISIAQ), and its former President (1994–1997) and a founding member and the president of the Finnish Society of Indoor Air Quality and Climate (FiSIAQ) 1990–2005. He has also served as the president of Finnish Association of HVAC societies and FINVAC since 1995.

Appendix 3.
Self-assessment Form for institution:
Evaluation of Research in civil engineering in Estonia 2008–2012

A. GENERAL REMARKS

Filling this self-assessment form is obligatory for all institutions participating in evaluation. All data in this self-assessment form should represent research in civil engineering and should cover only R&D activities and R&D personnel (teaching staff and doctoral students are not included).

A.1. GENERAL INFORMATION ABOUT INSTITUTION

A.1.1. Institution (entity)
Address:
Phone:
Internet home page:

A.1.2. Contact person for the Evaluation in Institution
Name:
Phone:
Email:

A.1.3. Percentage that research in civil engineering represents in the research carried out in the institution

(Calculations should base on proportions of research financing. The fields of research in civil engineering are defined in question A.1.4. In your institution there may be many other fields of science represented, but we ask you to give the percentage that research in civil engineering stands for).

Percentage that research in civil engineering represents in the research carried out in the institution	… %

In the following questions you are asked to concentrate only in this portion of research.

A.1.4. Institution's research profile within research in civil engineering *(give estimate of the percentage)*

(Calculations should base on proportions of research financing. The percentages should add up to 100.)

Research field	**(%)**
Structural engineering and construction materials	
Mechanics and marine engineering	
Construction economics and management	
HVAC, energy performance and building physics	
Road engineering, transport and geodesy	
Architecture, urban planning and landscape architecture	
Total	**100%**

A.2. PERSONNEL *(Number of research-involved personnel based on Estonian Research System).*

Detailed data about personnel is available in Estonian Research System. Information about recognition of staff is available in Estonian Research System. List of project-related staff with links to researcher's CVs is available in Estonian Research System.

Staff / year	**2008**	**2009**	**2010**	**2011**	**2012**
Teaching staff (if relevant):					
Professors					
Docents					
Assistants					
Lecturers					
Research staff:					
Research Professors					
Leading Researchers					
Senior Researcher					
Researchers					
Administrative personnel					
Total					

A.3. RESEARCH FUNDING *(Sum on financing in euros based on Estonian research System)*

Detailed data about research projects (incl. description and outcomes) and funding is available in Estonian Research System.

Source of funding / year	**2008**	**2009**	**2010**	**2011**	**2012**
Targeted financing projects					
Estonian Science Foundation grants					
National R&D programs (also from different Ministries)					
Other public financing (eg Enterprise Estonia, Ministry of Agriculture, Environmental Investment Centre, local authorities, etc)					
EU Framework Programme projects					
Estonian research contracts					
Foreign research grants and contracts (excl EU FP)					
Total					

A.4. RESEARCH OUTPUT *(number of publications and patents based on Estonian research System)*

Detailed data about research output is available in Estonian Research System. There is also complete list of publications and the list of best publications (max 30) with links to full text.

Total number of publications and patents (2008-2012)	Number
Articles in journals	
A book/monograph	
Articles in proceedings/a chapter in a book or in a collection	
Editing scientific publications	
Published meeting abstracts	
Other publications	
Patents / patent applications	

B. THE INSTITUTION'S SELF-ASSESSMENT

B.1. Short description of R&D activities and organisation.
(max 1 page)

B.2. Summarise your most significant scientific achievements for the period 2008–2012.
(max 1 page, max 5 achievements)

B.3. Summarise your most significant societal and professional achievements / impact for the period 2008–2012.
(max 1 page, max 5 achievements considering norms, standards, guidelines and other professional activities, industry contacts, collaboration with different professional unions, TV or radio shows, regular seminars etc)

B.4. What are the future plans for your institution in terms of …
a) … direction of the research area?
g) … direction of the research institution?
c) … direction of the national and international cooperation?
(max 1 page in total)

B.5. Most important national collaboration.
(list max 5 most important national research partners, max 1 page)

B.6. Most important international collaboration.
(list max 5 most important international research partners, max 1 page)

B.7. Please discuss what Strengths, Weaknesses, Opportunities and Threats that you see at your institution.
(max 1 page)

C. ADDITIONAL INFORMATION

- Appendix 1. Information about PhD students, thesis topics and supervisors. Obligatory, if applicable.
- Appendix 2. Information about Master students, thesis topics and supervisors. Obligatory. Information about research infrastructure is available in Estonian Research System.

Appendix 4.
Data provided by the Estonian Research Information System ETIS

- **R&D activities:**
  - List and description (incl. project number, title, description, project leader, senior personnel, duration, financing) of R&D projects;
  - Summarized data tables.

- **R&D infrastructure:**
  - Number and total area of labs and other research related rooms and facilities;
  - List of most important equipment, apparatuses and instruments (up to 30 and advisably with minimum cost 10 000 euros).

- **Personnel:**
  - Names, positions and CV-s;
  - Summarized data tables by positions held;
  - Age structure table;
  - Defense of doctoral dissertations;
  - Implementation of doctoral studies;
  - Awards and recognitions.

- **Outcomes of R&D activities:**
  - List and description of publications by classification;
  - List and description of other R&D based activities;
  - List of most important publications (up to 30) with full text;
  - Number and description of patents, patent applications and plant variety right certificates.

All data are from period 2008–2012.
All sections have options for making comments.

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