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Evaluation report 2004

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# Evaluation of Swedish Building Research 1993 – 2002

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# **Evaluation of Swedish Building Research 1993 – 2002**

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The Swedish Research Council for Environment, Agricultural Sciences and Spatial Planning (Formas) has a responsibility to finance high quality research of relevance for the building sector. The research shall contribute to increased knowledge, long-term strategic competence and sustainable development of the building sector.



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# Preface

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Part of Formas responsibility is to initiate and organise scientific evaluations of the research financed by the council. Since Swedish building research has not been evaluated in a systematic way since the late 1980's, Formas decided to evaluate the scientific quality of some important areas of Swedish building research. The institutions involved are the Royal Institute of Technology, KTH, in Stockholm, Chalmers University of Technology, Gothenburg, Lund Institute of Technology, LTH, in Lund, Luleå University of Technology, LTU, in Luleå, and the Swedish National Testing and Research Institute, SP, in Borås. The evaluation covered research conducted during 1993 – 2002.

Government spending through Formas and its predecessor the Swedish Council for Building Research, BFR, on building research in these institutions over the ten year period amounts to almost 700 million SEK and when co-financing is taken into account, the total amount is almost 1 billion SEK. The purpose of the evaluation was to assess the scientific quality of Swedish building research in an international perspective. In addition, the relevance of the research for industry and society was also investigated. Formas invited a renowned group of international experts to form an evaluation panel to advice Formas and produce an evaluation report. The panel's advice and recommendations for further research and scope of work is expected to be of great value to Formas, as well as to the universities and institutes concerned.



Lisa Sennerby Forsse  
Secretary General  
Formas

The basic data and published material submitted by the research groups was sent to each of the panel members during the autumn of 2003. In the first week in February the panel met in Stockholm for hearings with the groups. The panel chair submitted the final report in March 2004.

On behalf of Formas I am very grateful to the expert panel chaired by Professor Tuija Vihavainen for their skilful and efficient work in evaluating a large number of research activities in a broad range of building research. Their findings and recommendations to both the Technical Universities and SP as well as to Formas are much appreciated.



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# Summary

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The evaluation covered building related research in four Swedish universities and one institute. Due to the wideness of the field the evaluation report deals with both general aspects and the most significant findings and does not explore research themes or groups in great detail.

The research is strongly focused towards sustainable development and covers aspects relevant to the society and national economy. Scientific quality is in general significant and in some fields excellent in comparison to international standards. However, the results of Swedish research are not known well enough in the international scientific and professional arenas. The institutes should strengthen their international positioning and the impact of Swedish building research by increasing international publication and networking.

The research base is dispersed into a large number of relatively small research groups, which may lack critical mass. Depending upon the determination of the boundaries, about 70 – 80 research units were considered in the sphere of the evaluation. The institutes should consider strengthening and sharpening their research profiles by focusing into larger, more viable units in key research areas. Strategic co-ordination of the stronger areas and partnering and collaboration among the institutes should be pursued to improve research efficiency and effectiveness.

The increasing cost of maintenance and operation of well-equipped laboratory facilities and access to laboratory space are causing increasing problems in many research areas. The institutes should consider new opportunities for shared laboratory facilities through collaboration and alliances, both nationally and internationally.

To meet the evolving future needs, it will be important to integrate all aspects of sustainable development, including human, social, technological, environmental and economic perspectives. Cross-disciplinary activities and interactions between sectors

in the building and infrastructure areas are important for the identification of new emerging research areas.

The exploitation of research outputs and integration of innovation processes should be vigorously promoted. The institutions should strengthen the strategic dialogue and interaction with the industry and other stakeholders, engage industry more in research and give stronger assistance to the implementation of research results in practice in order to increase the competitiveness of the Swedish building industry and other associated businesses.

Formas is a significant supporter of research in the institutions. An important role for Formas is to promote partnering within and across the institutions and other stakeholders and formation of multidisciplinary research consortia through large-scale managed research programmes.

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# Scope

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The Swedish Building Research Evaluation focused on three main areas:

- 1 Science and Technology of Buildings and Built Environment
- 2 Technology related to Infrastructure and Spatial Planning
- 3 Land and Water Resources Engineering including Ground Water, Rock and Soil Engineering



Architectural Research was not included in the evaluation because that area will be dealt with in a separate evaluation during 2004/2005. Energy research was also excluded due to the fact that the Swedish Energy Research Programme has recently been evaluated by the Swedish Energy Agency in cooperation with Technopolis.

**This led Formas to the following scope:**

- Four Universities and one Research Institute
- One decade
- Three main technical/scientific areas

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# Evaluation Process

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As mentioned earlier in this report the Technical Universities, SP and Formas representatives held meetings during the spring of 2003 to discuss the scope as well as the organisation of the evaluation process. A very positive attitude concerning an international peer review of Swedish building research was expressed from all parties concerned.

According to the initial time schedule the universities and SP should submit background material in English to Formas not later than the 15th of September. In late September and beginning of October the material was sent to the members of the panel together with guidelines for the evaluation process. A meeting also took place in the beginning of November 2003 with Professor Tuija Vihavainen and the Formas secretariat in order to discuss the evaluation process and practical issues. Some changes in the proposed areas of responsibility within the panel were made in October. An additional panellist was invited and the invitation was accepted.

## Documentation

In the end of January 2004 Formas secretariat received the preliminary reports from each expert on the panel. Each member of the panel was supposed to read and individually evaluate all the documents. According to the individual area of expertise and after consultation, each member was given the main responsibility for a certain research area – two experts in each area. The individual evaluation of the area should be an in-depth evaluation, while the comments on other areas might be more comprehensive. The preliminary reports were based on the requested written documentation in English from the Technical Universities and SP, which included:

- Overall presentation of the University/Institute, budget, employees, students, organisation and themes within the scope of this evaluation.
- Overall presentation of faculties, institutions, centres etc within the scope of this evaluation.

- Short presentation of research programmes and projects, aims, results (max. 5 pages/ program or project). Including CVs, number of PhD students, external financing, international networking, list of publication:
  - Peer review papers
  - Other international scientific publications
  - Swedish reports
  - Popular science publications
  - Others.
- Three copies of the five most important publications according to the universities/ institutes own judgment.

According to the guidelines the expert panel should look into the scientific quality of the research conducted. The degree of excellence of the scientists and research groups should be evaluated according to the common criteria used in the international research community. These criteria include:

#### **The problem to be investigated based on existing knowledge**

The emphasis should be on the formulation of how the research is related to present international knowledge in the field, what should be achieved with the project/ programme, the hypothesis to be tested and the degree of innovation. Does the problem require a multidisciplinary approach and how is that handled?

#### **The methodology chosen**

The reliability and relevance of the chosen methods in relation to available alternative methods. Are the methods chosen the best ones for studying the problem and are the reasons for the choice sensible? Are there other methods (more reliable, more recent) that should have been used?

#### **The achievements of preset goals and impact of research results**

How successful was the project? To what extent have the set objectives and goals been achieved? Do the results of the project/programme add new knowledge, further development and/or specific products to be used by the industry? Does the work carry forward the knowledge front of the research area? Are the results of interest to the scientific community, industrial sector and/or society at large?

#### **The competence of the researcher/research group**

The common way to judge the scientific competence is to consider the publication list. The scientific production in

#### **Evaluation criteria included:**

- **The problem to be investigated based on existing knowledge**
- **The methodology chosen**
- **The achievements of preset goals and impact of research results**
- **The competence of the researcher/research group**

numbers and importance should be ranked according to where results have been published:

- International journals with a peer review system
- Regional or national journals with a peer review system
- International book chapters and books
- Proceedings and reports in English
- Reports in Swedish

**High quality research of  
relevance for the building  
sector**

Other aspects to be analysed are the number of graduated PhD students, the number of post-docs at the department/group, visiting professors, the level of external funding, international research cooperation, invitations to give key-note speeches, awards and of course patents originating from the research conducted.

According to its instruction Formas should finance high quality research of relevance for the building sector and for the society at large. The expert panel was also supposed to evaluate the research according to some relevance criteria. The research conducted should preferably add to increased knowledge and improved performance on issues and activities for the building sector. One important relevance aspect is sustainable development. The research being evaluated should also be carried out with quality, efficiency and environmental considerations. Another important relevance aspect to be considered was whether the industry sector co-financed or in other ways participated in the research conducted. Research results published in a popular form should be part of the relevance analysis as well.

The panel met in Stockholm the first week in February 2004 at Hotel Hilton Slussen. The first three days were spent on half-day hearings with representatives of the selected Technical Universities and SP. During the remaining two days the expert panel discussed its draft report and agreed on a time schedule for finalising the evaluation.

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# Expert Panel

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The Formas staff consulted its national and international network for suggestions concerning panel members. The Technical Universities and SP were also asked to suggest internationally renowned members to the evaluation panel. Formas Secretary General made her final decision in June 2003 and invitation letters were sent to the panellists. By early August 2003 Formas had received all positive answers as follows:

**Professor Tuija Vihavainen**, Chairperson. Vice Executive Director, Technical Research Centre (VTT), Building and Transport, Finland. Her research contributions are mainly in the field of Wood Material Technology, and she has served as Research Manager of Forest Products and Building Materials and Products at VTT. Tuija Vihavainen chaired the evaluation process including hearings and internal discussions and deliberations within the expert panel.



**Professor Richard Ashley**, School of Engineering, Design and Technology, University of Bradford, England. Specialist in areas like Environmental & Public Health Engineering, Sustainable Systems, Waste and Environmental Management, Marine Civil Engineering, and Hydraulics.



**Professor Einar Broch**, Department of Geology and Mineral Resources Engineering, Norwegian University of Science and Technology, Trondheim, Norway. Professor Broch has in addition to academic activities as private consultant participated in the design and construction of a wide variety of projects, mainly related to tunnelling and underground works.





**Dr. Jörn Brunsell**, Norwegian Building Research Institute (Byggforsk), Oslo, Norway. Main research fields: Energy Conservation in Buildings, Energy Efficient Ventilation Systems, Indoor Environment and Radon Mitigation Techniques.



**Professor Ulrike Kuhlmann**, Chair of Steel, Timber and Composite Structures and Director of the Institute of Structural Design, University of Stuttgart, Germany. Main fields of research: stability and fatigue assessment of steel structures, plasticity and ductility of joints and structures, composite structures, deformation behavior, connections, long term behavior.



**Professor Klaus R. Kunzmann**, holds a Jean Monnet professorship for European Spatial Planning at the School of Planning at the University of Dortmund, Germany, and is a Honorary professor of the University of Cardiff/Wales. Professor Kunzmann's main research interests are comparative urban planning and urban politics, creative urban and regional restructuring of old industrial regions, the role of culture and entertainment for urban and regional economic development, knowledge industries and urban development, urban and regional development in Asia and the education of urban and regional planners.



**Dr. S. Shyam Sunder**, Acting Deputy Director, Building and Fire Research Laboratory, National Institute of Standards and Technology (NIST), USA. The laboratory's mission is to meet the measurements and standards needs of the building and fire safety communities. The four program goals are: High-Performance Construction Materials and Systems, Fire Loss Reduction, Enhanced Building Performance, and Homeland Security. Dr. Sunder also serves as the lead investigator for the federal building and fire safety investigation into the World Trade Center disaster.

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# Results and Recommendations

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The background material submitted by the institutions was extensive and the research activities were in most cases presented on the level of research groups or even research projects. There were some 70 – 80 divisions, research groups or research units in the sphere of the evaluation, depending upon how the boundaries of focus areas are determined. Therefore the degree of excellence could not be evaluated on the level of projects as suggested in the Formas guidelines, and individual research themes cannot be discussed in this report in detail. The report concentrates mainly on the general aspects of the submissions and summarizes the most significant findings, providing key suggestions and recommendations by the evaluation panel. Due to their general nature, many of the recommendations addressed to individual institutions are equally valid to most if not all of the institutions.

# SWOT: Strengths and Weaknesses

## SWOT of Swedish building research seen from an international perspective:

### Strengths

- The research is strongly focused towards sustainable development and the needs of Swedish society
- The research covers a number of relevant aspects related to buildings, infrastructure and built environment
- Institutions undertaking building research appear open to international benchmarking as a means to improve their performance
- There is an apparent willingness for dialogue and constructive change among the institutions
- The scientific quality is in general significant and in some fields excellent in comparison with international standards
- The number of doctorates and licentiates has increased in building research in recent years
- Industry has generally welcomed the production of additional PhDs
- The research groups are working internationally, although mainly in the EU arena
- The system is open to and to some extent has been successful at attracting international academics to posts
- The adjunct professor system is very effective
- The ability of institutions to obtain external funding is generally impressive
- The diverse range of building related funders in Sweden provides opportunities for most researchers to obtain funding
- Industrial funding of building related research is broadly comparable with other countries

## Weaknesses

- Historically, the direction and quality of research groups has relied perhaps too much on individual professors/chairs
- A number of nationally important research themes are undertaken by relatively small research groups, risking a loss of competence in national capabilities should these fail or close
- International publication has only been modest in many areas compared with leading countries. Excellent Swedish research is not sufficiently known outside the country
- International networking is not pursued with sufficient vigour, leading to a lack of visibility world wide and limited opportunities for e.g. publishing or service on international committees
- Collaboration and partnerships are mainly restricted to the EU area
- Nordic co-operation has not been sufficiently exploited in building research
- There has been too little attempt to engage in infrastructure related research in developing countries for national aspirations.
- There is only limited exploitation of research results into and by national industry and stakeholders
- There is a lack of flexibility in funding of research staff that restricts opportunities for post-doc researchers
- Senior researchers have to devote too much of their time to bidding for competitive national research funding, detracting from their ability to carry out the research
- Current national funding system review processes are not very effective at assessing and hence funding multi-disciplinary research

# SWOT: Opportunities and Threats

## SWOT of Swedish building research seen from an international perspective:

### Opportunities

- Sweden (together with other Nordic countries) has the potential to become a European, and possibly a globally recognised centre of knowledge in the field of sustainable buildings and built environment
- The small relative size of Swedish building research activity makes it potentially more flexible and adaptable to respond to changing circumstances and needs
- There is a clear opportunity to develop an agreed combined future research strategy within and among the institutions that will make Swedish building related research more efficient
- The institutions can further improve their international positioning by focusing on their strongest areas of research
- There are opportunities for the institutions to develop a stronger market share for their research services world wide
- There are significant opportunities to produce more scientific publications to disseminate past and on-going research results to the international community
- Linking the Swedish building industry more closely with on-going research would improve the international competitiveness of the industry
- There is an opportunity to further develop Nordic co-operation
- There are new opportunities for shared laboratory facilities and access through collaboration, both nationally and internationally

### Threats/risk

- Problems are increasing in many research areas due to the increasing cost of maintenance and operation of well-equipped laboratory facilities and access to laboratory space
- Institutions are too reliant on research funds from the Swedish public sector. Private funding is too limited and short term insufficient to ensure continuity of research capabilities
- Within the institutions institutes of higher education, building related research is not considered as among the key areas of research
- Other countries and international institutions with greater critical mass can take over and exploit research markets currently led by Swedish research, compromising the viability of national research

## Key Recommendations based on the SWOT:

The institutions should strengthen the international positioning and impact of Swedish building research by increasing the communication of research results to international academia and professional environments, creation of international contacts, more active participation in relevant networks and increasing the international mobility of researchers.

The relevance and impact of research should be improved by strengthening the dialogue between the research institutions and the stakeholder community, by getting industry in particular and other stakeholders involved in definition of future needs and strategic research areas and in steering/advisory committees and networks.

The institutions should vigorously promote the opportunities and benefits from exploitation of research and development outputs as well as assist with the adoption and implementation of the research outputs. This is principally in order to increase the competitiveness of Swedish building industry and other associated businesses.

Combined research strategy should be developed and agreed among and within the institutions carrying out building related research aiming at strategic partnering and collaboration to improve the efficiency and effectiveness of Swedish building related research.

It is essential that the institutions involved in Swedish building research and their stakeholders secure a well-founded support base that includes access to the key experimental facilities needed for education and research.

Nordic co-operation should be strengthened.

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# Theme Review

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## Science and Technology of Buildings

The theme area is very wide including building materials and structures, building physics and services, fire safety, construction processes, building economy and facilities management. The largest share of reviewed activities of the institutions fall under this theme. Due to the wide scope only a very general overview is given below.

### Building Materials

The research deals mainly with wood, cement, concrete and steel, and also with natural stone and rock-based materials. The research focuses on materials modelling, microstructure versus properties, durability, and influence of materials emissions on indoor air quality. SP has an internationally strong research group on concrete technology focusing on frost resistance, corrosion and environmentally friendly concrete. The building material research at LTH also concentrates on concrete. Research at Chalmers has been particularly on cement and wood-based materials, partly successfully covered also by structural chairs.

There is little research on new materials (composite materials, structural glazing, coatings, adhesives, functional materials, etc.) or on combined use of materials. Only LTU works on composite structures of steel and concrete. More research could be directed to the prediction of service life performance of materials and material combinations. Building material researchers should increase cooperation with generic material science in order to transfer and apply new knowledge into the building field.

### Structures (buildings and bridges)

Structural research is an internationally strong research field in Sweden - but mainly with the traditional approach to design, testing, and modelling of the performance of timber, concrete, and steel structures under static and dynamic loads. All the five institutions have significant activities in the field. The newly merged Department of Structural Engineering and Mechanics at Chalmers is an internationally very strong group with a high





scientific level (e.g. in finite element methods and dynamics) combined with more applied research. The divisions of structural mechanics and structural engineering at LTH also cover a broad scientific area, and the work of the group e.g. in the field of timber engineering is internationally highly acknowledged. LTU has an internationally active research group in steel structures and a comparably large division in structural engineering with a high number of PhD students.

Development and application of advanced models and computational methods are pursued at LTH and LTU, but in general the emphasis on these areas is too limited. Priority should also be assigned to build competence in new and advanced areas of research in probability-based risk and reliability assessment methods, assessment of life-cycle performance (durability, fatigue, etc.), structural condition assessment, maintenance and renewal of existing structures, and structural performance under fire load conditions. LTH has applied reliability perspectives both to construction and management of existing infrastructure, research at LTU includes risk and safety from an environmental and structural perspective and KTH and Chalmers have assessed maintenance and service life of bridges.

The research groups are also advised to identify and conduct research driven by innovations required to meet architectural needs (e.g., new materials, new system concepts and joints, etc.). Especially at LTH and Chalmers there seem to be chances to co-operate with architects.

Changed policy on cost of access to laboratory space is a serious barrier for critically needed experimental research in this field. In addition, the cost of operating and maintaining laboratory equipment is of significant concern. Alternative policies and strategies are needed to address the problem.

### **Fire Safety**

Research in fire safety is at a high international level in selected areas; SP hosts one of the leading fire research groups in the world.

LTH has a unique Swedish educational program in fire safety engineering. In co-operation with SP, university-based research programs in fire safety engineering need to be significantly expanded in areas such as fire science, fire modelling, and fire suppression and control technologies.

Dissemination of fire safety design information to architects in cooperation with architectural organisations should be strengthened.

The risk-based approach adopted in fire safety research has also been transferred to other fields of design and maintenance.

### **Building Physics and Building Services**

Sweden has been one of the leading countries in certain areas of research on building physics and building services for the past three to four decades. The research in building physics is focusing on energy and moisture in order to ensure energy efficient and moisture safe buildings. The main research topics include thermal insulation and air tightness of the building envelope, controlled ventilation, heat fluxes and storage and utilisation of solar energy (LTH, KTH, SP).

Priority should be assigned to maintaining and rebuilding competence in critical areas of moisture and energy research, e.g., moisture effects on indoor air quality and health, design of energy-efficient buildings, use of local renewable energy sources, and “passive house standards.”

There is a critical need to rebuild current limited research competence on building services engineering and automation for efficient use and conservation of energy in building operations, e.g., demand controlled ventilation, lighting, sensors and sensor integration, tools for real-time simulation and control, and durability.

The number of competent groups working in building acoustics is small. The group at LTH is working with sound transmission of materials and elements and sound insulation. The group at KTH is no longer able to carry out acoustic measurements, and the Room Acoustics group at Chalmers has directed activities into other fields. There is a need to develop a coordinated national strategy and plan for research in building acoustics that considers new construction methods, interactions with building services equipment, new architectural requirements, and noise pollution.

As regards building materials and structures, the cost of operating and maintaining laboratory equipment is a significant concern in this research field. The institutes should develop alternative policies and strategies to address and solve this problem with high priority.

## **Construction Processes**

One of the main objectives is to increase the productivity of the Swedish construction processes. Important research areas are procurement methods, project organisation and management, quality management, computer aided planning and CAD modelling (LTH, LTU, KTH) as well as information management in the building process (LTH). An innovative research field at LTU is the role of clients in the building process.

Research interest and competence in integration of information and communication technologies should be increased in order to enhance construction productivity. Co-ordinated national strategies and plans for research in this area should be targeted, including standard protocols for product model representation and exchange of product model data. Swedish research could benefit from developments in other countries such as Finland, UK, USA, etc.

## **Building Economics and Construction /Facility Management**

The institutions have strong research programs of international calibre in this field with significant interaction and involvement of industry. Areas of research include: productivity measurement, quality management, multi-project organizations, facilities management, life cycle assessment, organizational management, applications to environmental systems analysis, project partnering, and innovation incentives (Chalmers, KTH).

## **Recommendations**

Potential areas for expansion include:

- Benchmarking and metrics for quality, cost, scheduling, and productivity at the level of the project and the firm
- Economic impact assessment (life-cycle cost-benefits) for integrating innovative technologies and meeting societal demands for sustainable development
- Real estate and project financing
- Development and management of affordable and sustainable housing
- Recycling of housing and buildings

# Technology Related to Infrastructure and Spatial Planning

In this review, research activities in the areas of spatial planning, urban studies, built environment, transport and real estate management are covered under this heading.

In this context:

- Built environment encompasses research on the physical environment of buildings and structures
- Urban studies cover all research on urban planning and development, and on activities to maintain or improve the quality of life of citizens
- Transport includes logistics and traffic management where reported by the five institutions
- Spatial planning is seen as a field of territory related research on local, regional and national tiers of physical planning and related decision-making processes
- Real estate (asset) management, if linked to engineering rather than to economics and business management

Obviously, this wide array of fields represents a wide range of research arenas, usually not inter-linked and integrated at Institutes of Technology across Europe. Consequently, the participating institutions, presumably for mainly three reasons, have not reported most research in the above fields. Either it has not been considered to be a subject of this review, or it has not been supported by Formas, or relevant research is done at Schools and Departments other than Civil Engineering (e.g. Architecture, Transport and Logistics, Economic Geography, Social Studies or Business Management), or in Swedish or even Nordic research establishment such as Nordregio.

As a consequence, it is difficult to judge from this review, to what extent related research in Sweden is leading the field and internationally competitive. The review could consider only selected segments of the research fields, as reported by the participating institutions.

There is one more aspect to be taken into consideration. In times of deregulation, the declining appreciation of the welfare state, and the growing dominance of market related approaches to the development and management of the built environment, the field does not now receive as much political support in Sweden as it used to in the late 20th century.

Nevertheless, there remains the overall impression that, in the absence of long standing scientific traditions, as well as due to the dominance of teaching commitments, research in these fields is carried out at the Schools in a very individualistic manner, depending rather on the interests and the competence of individual researchers. There are only few established interdisciplinary research centres. And only few divisions of Schools of Engineering seem to have coherent research strategies and programs, and only few seem to benefit from major support of their home institutions.

However, there are some areas where research merits international attention and meets international standards. These research arenas are: architectural philosophy and environmental psychology at LTH or transportation, spatial impact assessment, urban governance and real estate development at KTH, transportation and logistics at Chalmers, or to some extent, cold climate built environment at LTU.

## Recommendations

- The university institutions should follow-up their efforts to organise a specified division of activities between them, based on their research traditions and competencies, taking into account the likely impacts of generation change and the decline in competence and international networks.
- A future strategy, as has already been effective in spatial planning research, may be to forge stronger Nordic cooperation in order to achieve certain trans-national economies of scale in research capacity. This could be achieved by establishing a small number of university centres of excellence in one location, or by encouraging the formation of inter-university networks. Baltic co-operation could be an additional dimension in this respect.
- Formas could play a moderating role in such efforts, by longer-term commitments in certain targeted subject areas, or by offering co-financing to a small number of research network managers.

- Experience and competence in Sweden could be used to build or strengthen international competence in research fields such as:
  - Spatial development in regions of low population density and population decline
  - Governing sustainable quality of the built environment in market driven urban environments
  - Holistic approaches to resource conserving management of the built environment, under cold climate conditions
  - Sustainable transport and logistics
  - Containing urban development by flexible space concepts, technologies and policies
  - Involvement of the civil society in urban development and spatial planning

The institutions should consider focusing their research attention on a combination of technological, social and economic aspects of the built environment. Sweden has considerable experience in this field and a thus a strong future potential. These developments should be accompanied by more intensive efforts to communicate research results internationally. This would also help to promote the attractiveness of Swedish research to international scholars, to PhD students as well as to post-doc fellows. It seems that the potential of Swedish universities in attracting foreign scholars and in initiating and leading European research networks has not yet been exploited to the maximum potential.

# Land and Water Resources Engineering including Ground Water, Rock and Soil Engineering

Water related research is active in scientific aspects of precipitation estimation, including climatic changes, hydrological processes, both rural and urban, groundwater, water and wastewater quality and coastal processes. A number of applied studies are dealing with the related engineering and management. A unifying perspective to water system management is the fundamental incorporation of sustainability concepts, and systems thinking (notably Chalmers).

There are a number of areas where cross-disciplinary research has been effective. Despite this range of work, the research in these areas is of varying quality and often of limited significance internationally and is also being carried out by units that are too small to be sustainable. This is apparent as only a few areas are funded by e.g. EU or other international sources and the age profile of some of the key researchers is high. There are also indications that the current way in which this research is managed (within Institutions) and funded (externally) may inhibit more effective cross-disciplinary research.

The main areas of excellence include groundwater quality (including risk) and trans-national boundary water issues (notably KTH but in a number of Institutions), significance for resources and relationship to geotechnical engineering; cold climate hydrology and snow management (notably LTU and LTH); sustainability of urban water systems, including key pollutants and their control and socio-economic interactions (notably Chalmers but also including LTH and LTU); water supplies in scarce regions (LTH); coastal engineering (LTH). In the latter case, this important area has only a small unit of Swedish researchers. The provision of traditional hydraulics and hydraulic engineering is limited partly as a consequence of the high cost of maintaining laboratory facilities. There are some activities in this area but these primarily utilise numerical modelling rather than physical approaches.

It appears that the sustainable water cycle research is the only area of international leadership. Groundwater quality research, water scarcity management in developing countries and coastal engineering are on a par with other world-wide research and cold climate hydrology has some potential, but cannot be described as world leading. Most of this world leading or equivalent research

is very effective at producing high quality PhD students; has been published in top rated journals and maintains adequate levels of external funding. Although, in some areas, international funding is not at a level that would be expected, leading to too heavy reliance on internal Swedish funding.

Waste science and technology of relevance to the building sector has been included in a limited number of very specific areas. Of note is the Environmental Systems Analysis work at Chalmers, where products and process life cycles are dealt with. This work is on a par with the best world-wide and leading in some areas. Otherwise waste as productive materials for reuse/use of waste and secondary materials is being studied in e.g. highway construction by LTU, but this research is not internationally leading.

## Recommendations

- There should be a multi-faceted approach to managing research in this thematic area. Firstly the research that is currently internationally leading and of an international standard, should be supported. This is in the following areas:
  - Sustainable water and wastewater systems (including water scarcity and sludge management)
  - Groundwater quality and protection
  - Coastal engineering
  - Environmental systems analysis – including multi-disciplinary linkage to socio-economics
- In addition, the following emergent areas should be supported to help them achieve the same standing:
  - Cold climate hydrology, in association with key international partners
- Other areas of future importance in Sweden should also be targeted:
  - Integrated sustainable development (across all sectors but using the results from the urban water programme as a starting point) – requires multi-disciplinary activity.
  - Climate change and impact management, to include futures, precipitation prediction, building drainage, local drainage and main drainage as well as coastal protection.
  - Interactions between sectors in the building and infrastructure area.

# Geoengineering

In the context of this report, the research area Geoengineering includes: Engineering Geology, Geotechnical Engineering, Soil Mechanics as well as Geological Materials. All five institutions evaluated have departments or groups within one or more fields of this area. Due partly to tradition and to regional localisation the different universities have focused on different aspects of the broader field.

Typical is that the university in Luleå with a strong connection to the mining industry has concentrated on aspects of rock mechanisms such as blasting processes and stress related stability problems in deep mines. Together with the Swedish Blasting Research Centre based in Luleå they are undoubtedly in the forefront of this field. Also soft clay problems in the West coast area may be the reason for Chalmers being strong in this field and for their continuous development of laboratory facilities for soil testing.

Groundwater is a valuable resource. Research carried out at Swedish universities has brought the research capabilities to a high international level in this field. It is praiseworthy that international training programmes are now offered to developing countries.

Aggregates and natural stones are important materials for the building and construction industry. It is appropriate that a national laboratory like SP is developing competence in this field. This competence is now world class. It is therefore recommended that the universities involved in research related to these topics co-ordinate their efforts with SP and thus benefit from contact with SP:s established international network.

Prevention and control of water leakage has become an important topic with the increasing development of subterranean storage in urban areas and proposals for storing nuclear waste in rock caverns. A significant national research programme was started in this area some years ago. Comprehensive research in this

area has been and is still being carried out at KTH and Chalmers. Swedish researchers have probably devoted more time and effort on studying grouting of rock masses around tunnels and caverns than any other nation, with seven completed PhD theses and seven ongoing. Considering the serious leakage related problems reported from major projects like Hallandsåsen and Södra Länken the question may, however, be raised as to what extent the results of the research efforts have reached the appropriate organisations and people.

In Sweden tunnels are often important parts of the infrastructure. Planning, construction and support of tunnels are therefore topics, which are being studied at several universities. Considerable knowledge has been acquired. Inter-Nordic collaboration may bring further advance to this field.

Geophysical measuring techniques are studied and have been successfully developed at Lund. This field of research may, however, be outside the scope of this report.



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# Review of the Institutions

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# Royal Institute of Technology, KTH



## General Remarks

The presentation material available from KTH was less complete than the material from other institutions, which may in part reflect the evaluation results.

Research related to buildings and the built environment is carried out mainly in three Departments, Civil and Architectural Engineering, Land and Water Resources Engineering (LWRE) and Infrastructure.

The university and its programmes have a strong financial position. However, the use of laboratories has decreased due to high costs.

The university's record of doctorates and licentiates is significant. Many divisions have a good record of scientific and technical publications.

The departments and divisions seem to work in isolation and are only weakly operating in a coherent manner.

The Department of Civil and Architectural Engineering is lacking architectural expertise, or co-operation with the School of Architecture is underdeveloped. The Division of Environmental and Natural Resources Information Systems has recently completed projects on the influence of urban areas on local climate and remote sensing and GIS in groundwater hydrology. Currently there is only modest activity in this area and it may be that this division would be better integrated elsewhere.

In the Department of Land and Water Resources Engineering, there are areas of strength in the fields of water resources and related activities. Notably research on groundwater quality and management is of international standard.

The Department of Infrastructure seems to have a very wide agenda encompassing most of the aspects of socio-economic infrastructure management and systems analysis.

## Recommendations

- Develop common vision and strategy for the future to drive research and staffing
- Develop collaboration mechanisms to plan and conduct interdisciplinary research programmes to meet evolving needs; e.g. take advantage of the university's strong commitment and record of establishing Competence Centres
- Strive for increased industry participation and funding and more effective use of research results
- Strengthen laboratory access to support experimental research
- Strengthen publication in international journals in areas, where Sweden has a strong comparative advantage
- Increase the number of international scholars in research centres to add to the reputation of the university as a centre of international excellence
- In building engineering, create continuing dialog and collaboration with architects and transport planners to identify research needs for new system concepts
- In water related research, there are too many small areas of activity that lack critical mass and are not likely to yield major new innovations. Consider focusing water related research into a few key areas only. Initially groundwater and related activities should be a main theme.
- In the Infrastructure area, there are potential important collaborative links in socio-economics, with EU finding that could be built upon. The perspective could be very useful to complement the other departments' more technocentric approach
- It will also be important to identify emerging research areas and to develop new young researchers to add a limited number of core areas and to ensure security for decline in the current main strengths



# Chalmers University of Technology, Chalmers



## General Remarks

The School of Civil Engineering at Chalmers is among the leading civil engineering research institutions in Europe and beyond. The unifying theme is expressed as 'sustainable development'. The overall profile is in environmental systems thinking for buildings and infrastructure, and in the interaction between Technology, Mankind and Nature.

Chalmers has well organised programs and crosscutting collaboration among the disciplines. Generic research methodology (theory - laboratory experiments - case studies) is well implemented in all fields.

All departments are productive in publishing research results in international and national journals and in disseminating the results to the general public. External research funding is significant.

A significant proportion of the academic staff is young and there is a strategic approach to develop these into full Professors to replace retiring staff and to promote research staff via tenure track schemes. Chalmers has a significant record of PhDs and licentiates, many developed from MSc students (with quality improving). Also the number of associate and adjunct professors is significant.

Certain departments show strong international co-operation activities. There are some major international alliances and a number of EU funded projects. Examples are key links and sabbaticals with MIT and US and Japanese funded collaboration.

The institution has particular strengths in building physics, building economics and management and in environmental systems analysis. Chalmers is among the leading research institutions in Europe in applied acoustics.

Chalmers is also very strong in the area of water resources engineering across a number of disciplines and in managing high

quality multi-disciplinary work. Chalmers co-ordinates the national Mistra Urban Water Project (world leading). There are key interactions between Geo-engineering (really land related research) and Water Environment Transport. Both have a problem solving driven approach. A new centre funded by industry (FRIST) is dealing with contaminated areas.

A major joint centre Construction Management and Environmental Systems Analysis (COMESA) for environmental systems analysis and building economics and management, is linked with Mistra Urban Water project, but mainly working in products and systems. COMESA aims at bridging competences in engineering and social sciences.

## Recommendations

- Develop a common vision and strategy for the future including leadership
- Follow-up on efforts to profile building research among Swedish (Nordic) universities
- Continue with cross-disciplinary activity and new centres
- Seek more co-operation of Chalmers architects in research activities on the built environment
- Further extend international links. International recruitment of scholars and international post-doc students could be increased.
- Support appropriate industrial experience of academic staff Rethink the laboratory access policies and fees since their decline is hindering experimental research. Laboratories "at hand" are necessary for internationally recognised research and qualified education of students.
- The decision to invest in 'environment' some years ago has paid off. In the future, a better balance within all aspects of sustainable development should be pursued.
- On-going work with social, planning and governance areas could perhaps be increased.

# Lund Institute of Technology, LTH



## General Remarks

LTH as a part of Lund University has a broad basis for interdisciplinary research. The built environment, at different scales, from the region to the city and the building to materials and technology is a priority area at Lund University.

LTH has developed an impressive profile of broad international reputation in education and research. The research concept is ambitious. All divisions also seem to have a good scientific quality and large scientific production in terms of papers, articles and reports. LTH emphasizes appropriate balance between basic and applied research, and the divisions and departments seem to have relatively large external financing. There are, however, a large number of individual units, some of which may no longer be economically viable as each has to be self-sufficient.

LTH is transforming from the chair/division structure to a stronger and more efficient model of larger business units. The institution wishes to move forward from simply getting PhDs as baseline for research to a position where senior researchers can undertake research at high level.

LTH staff has had a positive experience by successfully competing for peer reviewed funding from Formas. However, researchers experience difficulties in getting funding for truly multi-disciplinary research.

The research record and international orientation of the Division of Water Resources and the Division of Building Materials are particularly impressive. LTH Division of Building Physics has been an inspiration for building physics researchers in the Nordic countries and a pioneer in the development of theoretical building physics as a discipline. LTH has strong programs in timber engineering, fire engineering, moisture and energy research and use of ICT. The staff complement for structural engineering is sub-critical in size to ensure adequate coverage.

Research in the Department of Architecture is largely individual, and not of a very high profile. Research in the theories of urban design is more significant. The research unit in environmental psychology is strong and significant, contributing to research in the field of “man-and built-environment-interaction”.

The regional dimension of the institute is not as well developed as it could be.

## Recommendations

- The stated multi-dimensional goals of research on the built environment at LTH are well articulated. Their transformation into research programs and projects, however, will require more effort to fill obvious gaps, and to encourage integrated approaches.
- Co-ordination with other Swedish universities has to be pursued to further strengthen and sharpen institutional profiles. Liaise with other research institutions to reduce competition and plan strategically.
- Exploit large research base, but concentrate on mergers and strategic alliances to build viable units. Consider reducing the number of separate units and concentrate in key areas.
- Invest more in adjunct professorships to benefit from practical experience of professors
- Encourage support (money and staff) to realise research goals for the built environment
- Aim for more EU projects and widen collaboration circle.
- Develop the interdisciplinary field of Technology and Society further into an international strength of the institution
- Develop vision and strategy for structural engineering research including staffing and cooperation with architects and fire safety engineering
- Develop vision and strategy for fire safety engineering research including staffing in cooperation with SP and other international fire research organisations

- Develop unified vision and strategy to revitalise building physics, energy use in buildings and building services research
- Re-integrate Water and Environmental Engineering into Water Resources Engineering
- Review the position of coastal engineering research area in preparation for new Formas initiative in climate change adaptation. Consider also more investment in flooding and river management area to complement this.
- Extend the emphasis on 'environment' to include all aspects of sustainable development.

# Luleå University of Technology, LTU

## General Remarks

Luleå University of Technology is a young and strongly developing institution with a high level of motivation.

In research related to buildings and built environment, sustainable development is a priority area. New research ventures are global resources and risk and safety.

The level of external research funding is high with a significant support from industry. The University has a very good policy for adjunct professorships to give links to industry and support fund raising.

LTU has a clear view on strength areas and the activities are well internationally linked in some areas, including a number of EU projects (e.g. steel structures).

An aspiration is apparent from individual specialists towards a wider perspective; e.g. broader vision and overcoming material borders in structural engineering and design applications.

Water supply technologies research appears to be unproductive. Waste science and technology has been productive for reuse/use of waste and secondary materials in highways, but not internationally active. Niche areas are cold climate storm water and possibly hazardous substances



## Recommendations

- Develop a common vision and strategy for the future, including leadership
- Carry out proposals to establish FEM Laboratory as a service function for structural mechanics within the department
- Increase publication in international journals; support researchers being on editing boards and other similar activities

- Continue current approach to acquiring external research funding
- Encourage technical assistance to local communities and consultants
- Develop and maintain experimental competence in structural engineering for northern Sweden
- Encourage collaboration between the divisions of timber structures and wood technology (wood material, wood physics, wood technology)
- Develop further the strength of cold climate technology.
- Strive to be internationally more visible in niche areas such as cold climate energy conservation and cold climate urban drainage, and invest in new links and co-operation with research in similar climatic conditions (e.g. Canada and Russia).

If proposed new priority areas (global resources and risk and safety) are genuine, there is a need to look more closely at integrating the current disparate activities in a coherent and structured way.

# Swedish National Testing and Research Institute, SP

## General Remarks

SP has a clear vision and a strategy to become a “world class institute” and primary centre of Swedish applied research with unique equipment. SP offers an organisational framework for integrating smaller institutes.

SP conducts multidisciplinary research for industry and society. Building research is a strong component of SP. The Institute has broad contacts with industry. SP sees itself as a strong research partner of universities and wants to help to connect universities with industry. A number of staff are involved in the training programmes of the universities, as adjunct professors, teachers or PhD students.

SP has an impressive record in developing test methods and active participation in standardisation. The institute is actively involved in EU standardisation and research networks and has experienced project managers with high competence to manage large national and international projects.

SP has strong income in a diverse range of areas, with modest year on year growth despite increasing competition in a smaller market. Further internationalisation of research and staff will become crucial. The institute needs to become more competitive worldwide if it is going to compete in research and global knowledge provision to multinational construction companies.

SP has one of the leading fire research groups in the world and it complements educational programme at LTH. Research in concrete technology and in building physics is among the leading research groups in Europe. Research on wood and wood construction will be more important in the future – especially in sophisticated applications for buildings. The institute has already taken a good move by integrating a wood research institute.

The institute has a significant record of low cost dissemination of research results to practitioners. As an example, SP meets eco-building ‘myths’ with scientifically based information



## Recommendations

- Prepare for more international competition.
- Sharpen the research profile further towards product and process innovations
- Be more active in influencing government and the restructuring of Swedish building research
- Consider further improvement of dissemination; e.g. internet solutions
- Develop general policy (access, pricing, hands-on use) for laboratory research to attract the universities
- Review policy with regard to developing country projects to expand markets
- Strengthen adjunct professor system further (perhaps with more University to SP links, as well as the other direction)
- Explore further strategic linkages with other institutions and identify new research areas
- Collaborate with architectural organisations for areas of common interest (fire and structural design, energy, eco-buildings etc.)
- Develop strategy for IT integration and automation including planned work on pre-fabrication
- Strategy for acoustics research needs to be better defined
- External funding for fire research need to be developed as a high priority

# Suggestions/ recommendations to Formas



## Suggestions/recommendations to Formas

Formas should undertake, together with other stakeholders, to **produce a vision, strategy and plan for the future development of Swedish build-ing** and building related research to meet national needs and enhance international competitiveness.

Develop and maintain a **balanced and mixed funding portfolio**, to include:

- individual investigators and graduate students
- larger managed programmes for selected targeted research areas
- rapid response financing for short term-term projects.

The **distribution of funding** between the various areas should be continuously **reviewed**.

The funding of high-risk research should be promoted due to the potential for innovation.

Within the large-scale managed research programmes, **promote partnering** (within and across institutions and other stakeholder groups) and the **formation of consortia** (national and international) emphasizing **multi-disciplinary research** and **research co-funded** with industry, other stakeholders and interested parties.

Include a **pre-proposal screening phase** for competitive funding bids to minimise the resource burden in the preparation of proposals by bidders.

**Maintain the current research rationale**, which is to promote the advancement of knowledge and ways in which sustainable development may be attained. This strategy is to include intrinsically the integration of technical, human, social and environmental perspectives.



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# Appendices

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**Appendix 1** Royal Institute of Technology, KTH

**Appendix 2** Chalmers University of Technology, Chalmers

**Appendix 3** Lund Institute of Technology, LTH

**Appendix 4** Luleå University of Technology, LTU

**Appendix 5** Swedish National Testing and Research Institute, SP

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## Appendix 1.

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# Royal Institute of Technology, KTH

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### Overview

KTH was founded in 1827 and is Sweden's largest technical university and it provides one-third of Sweden's engineering studies and technical research at post-secondary level. KTH trains architects and engineers at Master's and Bachelor's level, as well as doctors and licentiates. Associated colleges are found in Stockholm's surroundings – KTH Syd (Haninge and Södertälje), Information Technology, IT (Kista).

KTH is an international institution with collaboration on research and education exchanges, especially in Europe, the USA, Australia, and Southeast Asia. Cooperation schemes with the Baltic States and Russia are on the increase.

KTH is organised in one faculty of engineering and about 25 departments. Each of them possesses scientific competence for research and undergraduate education.

KTH has about 11.500 full-time students and 3.488 employees (964 women) – 210 professors (14 women). There are 14 study programmes in engineering. There are 1.490 active postgraduate and doctoral students (>50 %, of whom 27 % are women). The total turnover is 2.773 MSEK of which 1.349 MSEK is external financing.

The undergraduate programmes and the research activities cover the spectrum from natural sciences to the branches of technology including architecture, industrial economics, urban planning, work science and environmental engineering.

### KTH Targets and Strategies

#### KTH is to

- Become one of the top five technical universities in Europe and one of the world research leaders in information technology and biotechnology

- Become a leader in a number of important industrial development sectors in order to provide the best possible support to the Swedish community and its business life.
- Become a technical university with the status of a hub of industrial development in northern Europe.
- Contribute to regional development in the Stockholm area as a whole, by means of co-operation with government agencies, business life and other universities.
- Be a university that displays a dynamic profile characterised by curiosity and cultural diversity
- Be a university of reciprocal personal development between students and staff, recognising the differences in outlook, attitude and experience of men and women.
- Be a university with an international commitment to global technical problems as one of its characteristics, contributing to a sustainable environment, to peace and to increased prosperity.

### **School of Civil Engineering and Urban Management**

A new Master of Science program (civilingenjör) was started in autumn 2003. Merging the two existing schools Civil Engineering and Surveying into a new school named Civil engineering and Urban Management set up the new program. The objective of the new program is to give the students a modern education directed to planning, construction, management and administration of built environment. For the first year 140 students were recruited.

The complexity of the society of today requires education that can give a comprehensive view. The two first years are common for the students after which the program is divided into one more planning and administration directed part and another directed towards design, construction and environmental engineering. During the last year the students can choose between nine different profiles like traffic engineering, urban planning, real estate planning and land law, real estate management, geodesy and geoinformatics, environmental engineering, production management, civil engineering and finally building and building services.

The program corresponds to 180 points or 270 ECTS. KTH:s requirements for such education are that at least 100 points shall be mathematics, natural and engineering sciences. A master of sciences thesis shall be written during the last year corresponding to 20 points. All illustrated in the figure on page xx.

At KTH there are several different master programs. In the area of Built Environment and Urban Management, the following programs are given:

***Spatial Planning*** - Master Program is 1.5 years undergraduate study programme offered by the Department of Infrastructure. The aim of this international programme is to provide students with a thorough understanding of the nature of spatial planning and to develop the knowledge and skills necessary for a professional career in strategic decision-making positions (national or international) in industry and government.

***Real Estate Management*** - Master Program is 1.5 years undergraduate study programme offered by the Department of Infrastructure. The programme consists of three major parts, viz. foundation courses during the first term, real estate-related courses during the second term and a thesis. Core courses are Applied Economics (two courses), Research Methods and Basic Corporate Finance with Real Estate Applications. The second term consists of two core courses in Real Estate Market Analysis and Development and a continuation course in Corporate Finance. During the second part of this term, students may choose among courses in Real Estate Valuation, Real Estate Finance, Management of Land and Water and Facilities Management. The thesis consists of in-depth studies in a subject area within the scope of the programme

***Land Management*** - Master Program is 1.5 years undergraduate study programme offered by the Department of Infrastructure. The MSc Programme in Land Management is fully financed by the Swedish International Development Cooperation Agency (Sida). Thirty-eight students are accepted to the programme each year and granted a scholarship that will cover their own personal living expenses in Stockholm. The aim of the programme is to show the students how land management functions in a market economy and to prepare them for work in land management positions in their home countries. The focus of the courses is not on purely technical solutions, but rather on economic, legal and property formation/registration processes.

***Environmental Engineering (EE) and Sustainable Infrastructure*** – Master program is 1.5 years undergraduate study programme offered by the department of Land and Water Resource Engineering. The scope of Environmental Engineering (EE) and Sustainable Infrastructure (SI) is international and multi-cultural.

The subjects under EE attempt to provide an engineering approach to environmental problems, while SI focuses on the issues of planning and management taking into account ever-changing environmental scenarios and demands. Students will increase their understanding of the functioning of ecosystems, learn how to assess local and global environmental impacts of human activities, and investigate how to modify them via physical and bio-chemical interventions.

The studies cover the phases of policy generation, project design and implementation, as well as operation and maintenance. The methods and techniques of urban and regional development, which are covered, are those that incorporate the demands for environmental protection, and sustainability of development agendas at local and global levels. A shift from centralised approaches in management and planning towards the strengthening of community participation characterises the body of methods treated.

The goal of the programme is thus to educate an engineer, planner or manager with strong skills of communication, one who can provide leadership in their area of work based on the fact that they have an understanding of how different professions work and perceive issues, and one who is flexible and adaptable to change especially in an era of global environmental challenges.

### **Department of Civil and Architectural Engineering**

The department of Civil and Architectural Engineering was founded 2001 by the merger of eight divisions from different departments. These divisions have a common focus on the technical issues of design, construction and management of buildings and infrastructure. For building issues and installations the competence is well founded as well regarding depth as breadth and well connected to the problems actual for the design and construction industries. The competence regarding infrastructure issues is unique for Sweden with well established professor-ships for bridge, tunnel and highway structures. To support these themes there are divisions for steel and concrete structures.

#### **The divisions of the departments are:**

- Building Materials
- Building Services Engineering (Installation Engineering and Building Indoor Climate)
- Building technology (Building Physics and Building Acoustics)

- Environmental and Natural Resources Information System
- Highway Engineering
- Soil- and Rock Mechanics
- Concrete Structures (Concrete Construction)
- Steel Structures (Steel construction)
- Structural Design and Bridges (Bridge Construction)

### *Overview of Research in Each Division*

#### BUILDING MATERIALS

Environmental assessment of building materials, durability and service life of building materials, heat- and moisture storage in wood massive buildings

Research fields:

- Environmental assessment of building materials
- Heat- and moisture storage in wood massive buildings
- Service life planning
- Predicted maintenance planning
- Phase changing materials
- Service life of ACC-walls
- Solar energy supported heat pump systems
- Gluing of wood
- Durability planning of structures

#### BUILDING SERVICES ENGINEERING

Installation Engineering and Building Indoor Climate, simulation, ventilation, service and maintenance, pipes and ducts.

During the period 1993-2002 the Division for Building Services Engineering (ITEK) has had funding from BFR/Formas, cycling three-year grants as well as some additional grants. The Swedish Energy Agency (STEM), companies, and KTH have also provided funding. During the period eight PhD thesis have been accepted, and also eight Lic. Thesis. Most of these studies have been funded by BFR/Formas.

The aim of the research is: “To work for better quality in the building process, better indoor environment, and decreased use of energy in buildings by means of experimental studies and development of computer programs.”

Research fields:

- Ventilation
- Computer simulation
- Operation
- Ducts and pipes

## BUILDING TECHNOLOGY

### Building Physics and Building Acoustics.

The research of the Division of Building Technology concerns the functionality of the building in an integrated approach including subjects like Building Technology, Building Physics and Building Acoustics and in close relation with Building Materials, Building Services Engineering and Indoor Climate. The research and educational program is aimed towards components and system solutions for buildings to create a comfortable and healthy environment for human beings and to meet the specifications of industrial processes. Environmental, economical and technical sustainability is evaluated in a life cycle perspective.

The main areas of research during the period have been the following:

- *Building Physics* – heat and mass transfer with applications to buildings
- *Low energy design* – modelling, system solutions, design process, innovative concepts.
- *Applied building technology* – functionality and durability – quality assurance
- *Building Acoustics* – sound insulation and impact sound reduction and wind turbine noise
- Insulation of *buildings* against ground-borne noise from trains.

## ENVIRONMENTAL AND NATURAL RESOURCES

### INFORMATION SYSTEM

Remote sensing, geographic information systems and modelling mainly for environmental and natural resources applications.

## HIGHWAY ENGINEERING

The Division is currently performing research in the following areas:

- *Road Materials* – material properties and composition are of decisive importance for the performance of the road structure. It is important that research is carried out concerning the following road materials and components: bitumen, additives, aggregates, soil materials, and bitumen bound layers.
- *Paving Techniques* – several areas in asphalt technology are in need of research: cold technique, recycling of asphalt pavement, usage of alternative materials, and waste products.
- *Pavement Design*. Today's pavement design system is based on empirical knowledge of the performance of various existing designs. There is a considerable need for a more

general system based on mathematical expressions for determination of stresses in the road structure. The properties of the materials in various layers of the road structure constitute the input data in such a system. Insufficient knowledge of these material properties is one of the main reasons why no generally accepted system of bitumen bound pavements has been developed.

- *Road Maintenance Techniques and Systems* – measurements and analysis of road condition, business economic models for planning maintenance, description, measurement and evaluation of the effects of various issues, Pavement Management Systems (PMS), Bridge Management Systems (BMS), contractual forms for operation and maintenance.

#### SOIL- AND ROCK MECHANICS

The research perspective at the division is on design process, risk analysis and reliability applied for geotechnical structures in civil engineering. The research deals with phenomena and technology that have its origin from problems encountered mainly in infrastructure projects in Sweden or abroad.

The division is organized in three research groups. One group has its focus on soil mechanics and foundation engineering. Another group has its main activities directed towards soil and rock dynamics and the third group is working with rock mechanics and tunnelling engineering.

The research approach is mostly a combination of field experiment and modelling. Important tools for the research work are advanced technology for field measurements, analytical and numerical modelling and probabilistic methods and risk analysis.

The main activities are as follows:

- Grouting of hard jointed rock
- Rock support with bolts and shotcrete
- Design of undergrounds openings
- Stability of tunnels with no or low rock cover
- Risk analysis for construction in soil and rock
- Soil improvement
- Soil/rock-structure interaction
- Train and traffic vibration
- Foundations engineering

#### CONCRETE STRUCTURES

The research concerns analysis, dimensioning, structural design, safety, assessment, repair and strengthening of load-carrying

concrete structures for housing, industry and infrastructure. Both theoretical and experimental research is performed. The department has modern equipment for static and dynamic testing of materials and structures in the laboratory or in the field.

Current research fields:

- Development of new concrete materials for special applications
- Design of rock reinforcement structures, especially analysis and behaviour of shotcrete structures
- Foam concrete for house constructions
- Self compacting concrete
- High strength concrete for defence structures.

#### STEEL STRUCTURES

The research concerns analysis, dimensioning, structural design, safety, assessment of load-carrying structures of steel, aluminium and wood for housing, industry and infrastructure. Theoretical as well as experimental research is performed. The department has modern equipment for static and dynamic testing of materials and structures in the laboratory or in the field. The computer equipment, as well, is modern and intensively used.

Current research fields:

- Development of design methods to be used in the Eurocodes for steel and aluminium structures
- Light - weight steel structures
- Construction loads on shores and stability of horizontal formworks
- Development of new solutions and design methods for connections in ultra high strength steel
- Joints in aluminium structures.

#### STRUCTURAL DESIGN AND BRIDGES

The research concerns analysis and design of structures and bridges taking into account the structural stability, durability, aesthetics, environment, economics and social aspects. The last ten years, our research in the area of safety, assessment, and repair and strengthening of load-carrying structures have greatly intensified. Both theoretical and experimental research is performed. The department has modern equipment for static and dynamic testing of materials and structures in the laboratory or in the field.

Current research projects:

- Loads and load effects on bridges
- Bridge weigh-in-motion

- Studies of bridge-high speed train dynamic interaction effects
- Long-term monitoring and assessment of bridges
- Performance-based procurement of bridge maintenance
- Reliability, technical maintenance, rehabilitation, and economical service life of bridge structures
- Punching of plates and slabs
- Productivity development for the construction process of bridges
- New construction material and methods for the infrastructure
- Roads floors and pavements
- Design of long-span metal culverts
- Railway track engineering.

### **Department of Land and Water Resources Engineering**

The Department wants to participate and contribute to fulfil the demands of the society for a sustainable and effective utilization of natural resources based on the best scientific understanding and engineering. Studies of the natural resources are carried out from the perspectives of the societal needs coupled to the social sciences. The impacts of different cultural diversities in the utilization of natural resources are an important perspective of development. Knowledge and methods for utilization and protection of natural resources include all scales from the local to regional both within and across the national boundaries.

The doctoral programs presently include 5 disciplines: ground-water chemistry, soil and water resources studies, hydraulic engineering, water resources engineering and engineering geology. The undergraduate programs include the study programs in Surveying and Civil Engineering. A new program on Natural Resources Engineering was launched recently.

#### ***Overview of Research in Each Research Groups***

The research groups have been reorganised to better deal with ongoing research activities. Corresponding activities were carried out earlier during the names of ground water chemistry, water and sewerage, land and water resource engineering and water resource engineering (hydraulic engineering), engineering geology.

#### **ENGINEERING GEOLOGY AND GEOPHYSICS**

Examples of research include:

- Environmental geology - modeling coupled hydrological, mechanical the thermal effects on the geological environment

in connection with the disposal of nuclear waste.

- Environmental geophysics - geophysical investigations and drill core evaluations for determining the potential for geothermal energy.
- Engineering geology – development of new image analysis methods for the characterization of aggregate quality.

#### ENGINEERING HYDROLOGY AND HYDRO-GEOCHEMISTRY

The research group aims at combining natural science (coupled hydrological and biogeochemical) process investigations and modeling with engineering analysis, identification and design of environmentally and socio-economically sustainable scenarios for water management. This research is in collaboration with the Department of Physical Geography and Quaternary Geology, Stockholm University.

#### ENVIRONMENTAL GEOCHEMISTRY

The main focus is on interactions between Man and Environment, with emphasis on the chemical processes in soils and waters. Some examples of research areas are: arsenic in ground-water, geochemistry of recycled wastes, biogeochemistry of wetlands and modeling to assess the risk of metal leaching from contaminated soils.

#### ENVIRONMENTAL MANAGEMENT ASSESSMENT

The research group focuses on theories, methods and tools or sustainable natural resources management. The group is involved in a variety of research activities in cooperation with other leading

national and international research environments. Recent research efforts relate to integrated water resource management, reconstruction of the water utility sector, landscape ecological modeling, environmental impact assessment/ strategic environmental assessment, environmental information management and GIS decision support.

#### ENVIRONMENTAL MODELING

The main focus is on the development of suitable modeling tools to understand transport processes in the environment. The modeling is related both to the fundamental understanding of transport phenomena and to an efficient use of models for applied environmental problems.

#### ENVIRONMENTAL PHYSICS

Environmental Physics is the study of the physical processes in the environment and the interaction with biological and chemical

processes. Environmental Physics is an interdisciplinary subject that includes classical subjects such as soil physics, hydrology, hydrogeology, meteorology, plant physiology, ecology and microbiology. The main focus is on different processes within the soil-plant-atmosphere system.

#### HYDRAULIC ENGINEERING

Hydraulic Engineering is concerned with applied fluid mechanics and hydrology. The subject covers basic problems in rivers, lakes and dams. Water resources management and planning is also included. Current research deals with hydraulic structures such as dams, spillways outlet structures and river engineering. The main research approach is numerical modelling of flow and sediment transport.

#### WATER ENGINEERING AND RESOURCES MANAGEMENT

The goal is to develop and apply basic knowledge to improve different functions of municipal water, sewage and waste handling. The focus is directed towards different treatment methods combined with recovery of resources to achieve recycling in society. Both technical and nature-based methods are studied. Attention is also given to the interaction between water, waste and energy for improving the system function of municipal infrastructure.

### **Department of Infrastructure**

The Department of Infrastructure aims to be a global centre for research and education in the society's material and immaterial infrastructure. Together, this infrastructure forms the arena that either facilitates or limits economic, technological and social growth and development in the short and long term. The common denominator for the Department's activities is infrastructure.

By infrastructure, KTH means:

- Networks for the transportation of goods and people.
- Networks for the transfer of messages, that is, the communications network.
- The built environment and real estate structures, that is, the cultural environment.
- The natural environment.
- Social institutions, that is, abiding laws, regulations and decision systems.
- Common, abiding values.

The Department consists of a joint Graduate School and Divisions for:

- Urban Studies (Built Environment Analysis, Real Estate Planning & Land Law, Photogrammetry & Geoinformatics and Urban Planning)
- Systems Analysis and Economics (Building and Real Estate Economics, Philosophy, Transportation and Locational Analysis)
- Transportation and Logistics (Transportation, Logistics, Geodesy).

### ***Overview of Research in Each Division***

#### URBAN STUDIES

##### *Built Environment Analysis*

Research is mainly funded by external funds such as Formas, Sida/SAREC, the European Union, the City of Stockholm and private construction and housing companies. The major part of the research is oriented towards user requirements on the built environment and how changes in society may influence spatial qualities. Research production has as target groups national and local authorities, housing companies, constructions companies, practising architects and user organisations, besides the scientific community. Most research projects are carried out in co-operation with Nordic, European or other international institutions.

##### *Real Estate Planning & Land Law*

The most important research area is: Property transactions and real property formation procedures.

##### *Photogrammetry & Geo-informatics*

The division is also involved in the following projects administered by the Centre for Geo-informatics (CGI):

- Visualisation and Visual Languages
- 3-D Object Modelling
- Quantification of Landscape Structure

##### *Urban Planning*

The Urban Planning Unit Activities are currently concentrated in the following areas:

- Planning and decision making processes
- Local and regional analysis and development
- Governance and institutions
- Housing, social conditions and economic development

- Planning for sustainable development
- Culture, infrastructure and service

#### SYSTEMS ANALYSIS AND ECONOMICS

##### *Building and Real Estate Economics*

The most important research areas are:

- Financial Analysis
- Market Analysis
- Transaction Analysis
- Lifecycle Analysis (LCA)
- Real Estate Management
- Real Estate Information System
- Housing Economics

The research group is regular published in high ranked international journals such as Real estate Economics, Journal of Property Management, Journal of Real Estate Economics, Finance and Journal of Housing Economics. Associate Professor Mats Wilhelmsson won the Albert Aronsson Award in year 2002 and Associate Professor Åke Gunnelin won the Edgar Mill Award in 2003.

##### *Philosophy*

The Philosophy Unit at KTH teaches and performs research and postgraduate education on philosophical aspects of technology and its social applications. Our three most important research areas are philosophy of risk, ethics of technology, and logic and decision theory.

##### *Transportation and Locational Analysis*

The subject of Transport and Location Analysis comprises development of theories and models for studies of settlement, transport, communication and environmental systems with various delimitations and spatial resolutions. In the subject, tools for forecasting and analysis are developed for applications in infrastructure, spatial and environmental planning. Central areas of the subject are network-based demand and supply analyses, methods of estimation and model validation as well as computer-based forecasting and decision support systems. The subject is inter- and multi-disciplinary. It relies on methods from systems analysis, optimisation theory, statistics, and applied mathematics and computer sciences. Models and theories are developed with support from the department's own subjects of planning and disciplines like economics, geography, environmental and behavioural sciences.

## TRANSPORTATION AND LOGISTICS

### *Transportation*

Research on transportation is focused on planning and design of roads, railroads and other transportation systems. Analysis and evaluations of the transportation systems concerning function, allocation of resources, safety and environmental consequences are important aspects on our research.

### *Logistics*

*Logistics* is a young academic subject. The traditional focus on transportation and storage is developed into Supply Chain Management, SCM. SCM's focus is on integrated information and material flows in the whole supply chain or supply network. Academic research papers on SCM also often describe change processes in the chain. The project application concerns two courses; IH1204 Logistics, a basic course in supply chain management and IH1212 Logistics, an advanced course which focus is change processes in supply chain management. Our most important research area is:

- Experience-based learning in logistics
- Managing Customer-Supplier Relationships within the Demand and Supply Chain

### *Geodesy*

Research activities of the Geodesy Group have been well known internationally. At present, the Geodesy Group is engaged in three major externally funded research projects:

- SKB - GPS monitoring network for final disposal of nuclear waste
- GOCE - Gravity field determination using GOCE
- Formas - Monitoring of constructions and detection of motions by GPS

Other research projects are listed below:

- Methods for geoid determination
- Geodetic Aspects of the Law of the Sea (GALOS)
- Geodetic monitoring of the Vasa ship
- Integration of GPS with inertial survey technology
- Development of the Mozambican geoid model MOZGEO 2002
- Mean earth ellipsoid best-fitted to the earth surface

### Competence Centres at KTH:

KTH is responsible for nine of the VINNOVA - financed Competence Centres, and is a partner of another two of these. Additional 16 Centres, financed by other sources are also located at KTH. Of these the following centres could be of interest for the research on the Built Environment. All except for first two are linked to the department of Infrastructure.

- Environmental Science (CMV),
- Energy Conversion Technologies (CETET),
- Safety Research
- CDU – Performance and Maintenance of Infrastructure
- Centre for Bank and Finance, Centre for Operations and Maintenance,
- Centre for Real Estate Planning & Land Law,
- Centre for Geodesy & Geoinformatics,
- Centre for Environmental Strategies Research,
- Centre for Traffic Simulation and Centre for Science and Innovation Studies.

### Some Basic Figures of the Departments Involved

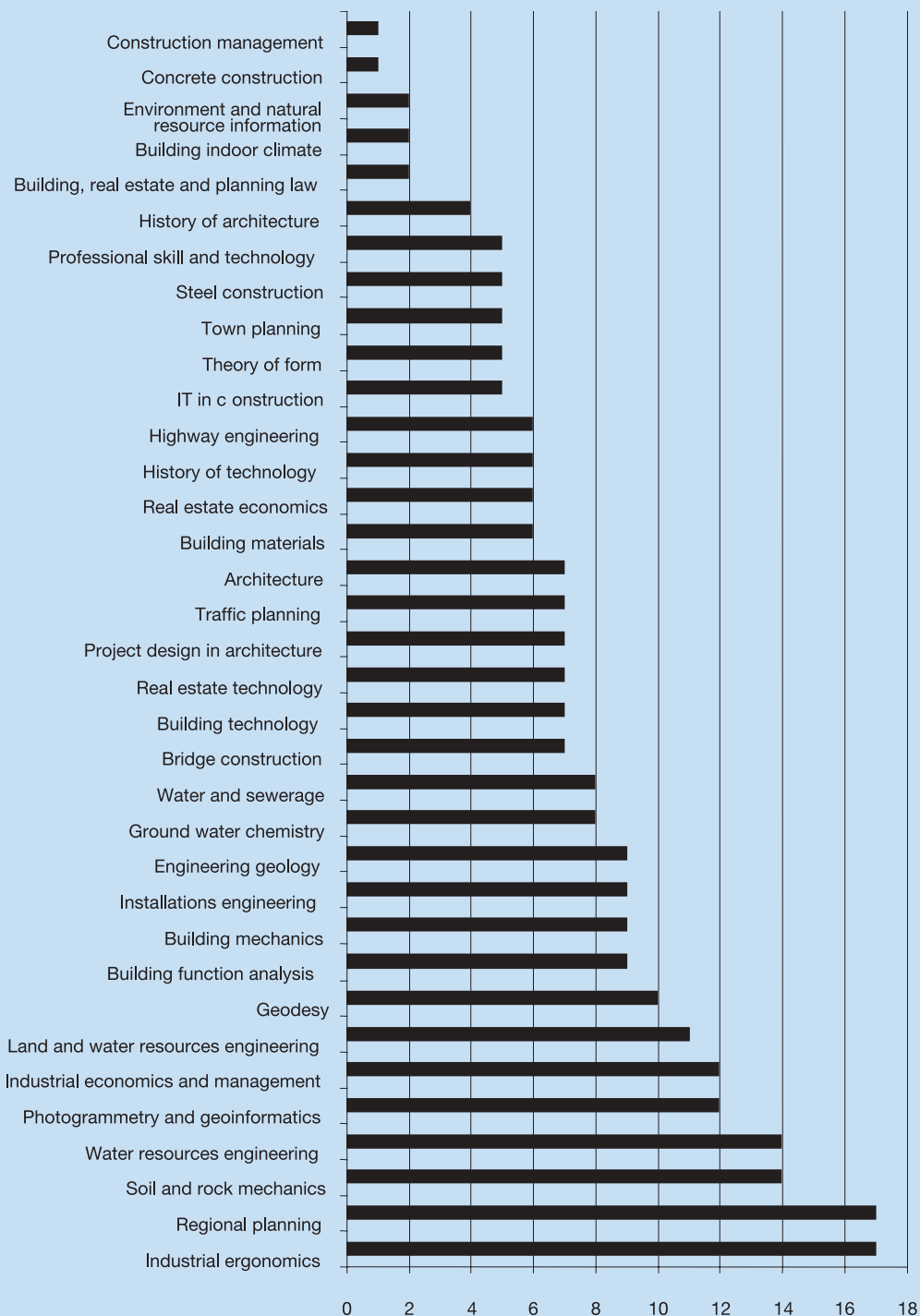
Department	Infrastructure	Land and Water Resources Management	Civil- and Architectural Engineering
Total number of employees at KTH	203	98	76
Professor	9	4	11
Adjunct professor	4	1	4
Guest professor	4	-	1
Associate professor	1	1	-
Senior lecture	19	8	6
Lecture	6	-	1
Researcher	32	15	10
Guest researcher	-	4	-
Research engineer	34	5	8
Administrative personnel /technicians	27	9	17
PhD. students (employed)	68	40	18
PhD students not employed at KTH with an activity more than 50%	33	6	22

*Detailed description of different categories employed at the department of Infrastructure, Land and Water Resources Management and Civil- and Architectural Engineering. 2004.*

Some basic facts	Infrastructure	Land. and Water Resources management	Civil- and Architectural Engineering
Total turnover for research work MSEK	96	42	49
Direct funding from the state to KTH MSEK	27	16	21
External funding except Formas MSEK	59	24	23
Funding from Formas MSEK and percentage of total turnover	10 (10%)	2 (5%)	5 (10%)
PhD examination per year (last 3 years and as a mean for years 1992 to 2002)	8.5 and 7.5	6.5 and 5.0	9.7 and 5,9

*Some basic facts about the research activities at the different departments. 2003*

## Degrees awarded in AILV area at KTH 1992–2002



*Students awarded a PhD-degree divided into different subjects connected to the Schools of Architecture, Industrial Economy and Civil Engineering and Urban Planning during the years 1992- 2002.*

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## Appendix 2.

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# Chalmers University of Technology

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Chalmers University of Technology was founded in 1829 following the will of William Chalmers. Chalmers became an independent foundation on July 1, 1994.

Around 13,100 people work and study at Chalmers, including more than 10,500 undergraduates. Each year close to 300 PhD and Licentiate degrees are awarded as well as 760 MScEng and MArch degrees. 40 percent of Sweden's graduate engineers and architects have been educated at Chalmers. Chalmers' turnover is approximately SEK 2.1 billion per year, around two-thirds of which is related to research.

Located on the Chalmers campus is Chalmers Science Park, the site of a number of company research departments as well as various University bodies involved in interaction with business and industry. Several hundred so-called spin-off companies have emanated from Chalmers and employ more than 20,000 people.

Research at Chalmers ranges from mathematics and natural sciences through to engineering, industrial sciences and community development. At eleven schools, divided into 60 departments and divisions, research and education are conducted within natural sciences and all the engineering science disciplines.

### **School of Civil Engineering**

The School of Civil Engineering at Chalmers covers research, education and development in most of the main fields of Civil Engineering. The sphere of activities covers planning, design, construction, operation and management of buildings and public works, technical systems and their implications belonging to them. In addition to this, the School covers an overall responsibility in Engineering Acoustics and HVAC (Heating, Ventilation and Air Conditioning).

**Mission:**

- To contribute to a society that promotes good health, a sound and safe environment and sustainability.
- To develop and hold our knowledge and scientific base in trust
- To educate and inform

**Vision:**

- To become one of the best Schools of Civil Engineering in Europe
- To develop a competent and successful staff
- To create a working and study environment that promotes progress

**Departments**

## APPLIED ACOUSTICS

The research at the department is performed in two groups:

- *The Vibroacoustic Group* - Today the focus of the research is put on three main areas, tyre/road noise generation, vehicle acoustics and community noise including different aspects of sound propagation outdoors.
- *Chalmers Room Acoustics Group (CRAG)* - Product sound quality as applied to aircraft and various types of ground transport, presence and ego-motion in virtual environments, Sound quality indoors and outdoors environments.

The Department offers an international master's programme on Sound and Vibrations. This program gives students a possibility to specialise in different fields such as vehicle acoustics, sound and vibration quality or design of silent products.

## BUILDING TECHNOLOGY

The research of the department is organised in three research themes:

- *Building Physics* – The research is focused on energy and moisture. In the energy area heat transport in buildings and district heating systems as well as storages for heat and cold are studied. The moisture research is oriented toward moisture safety in buildings and mechanical effects of moisture. Theory of coupled heat, moisture and air transport is a prerequisite for understanding of the physical processes.

- *Building Material* - At present, research mainly refers to cement and wood based materials and surface finishes on these materials.
- *Building Services Engineering* - The goal of the research is to contribute to the quality of planning and design of buildings and their technical systems. The factors that determine building services systems and components for commercial buildings (fulfilment of requirements, etc.) and the indoor climate, as well as international cooperation on large-scale solar heating systems, are important research topics.

The Department is responsible for the master's programme Performance Design of Buildings.

#### COMESA – CONSTRUCTION MANAGEMENT AND ENVIRONMENTAL SYSTEMS ANALYSIS

Two research groups work at the department:

- *Building Economics and Management* - The research considers economical and organizational problems within temporary multi-organizations. Most research starts from general organization theories and then specializes depending on the current problem. At present, most research is on construction projects, but the trend is more research on civil engineering projects. The research comprises the whole process, starting from a customer or client's idea of a building etc. ending with the demolition and how the rest material is used.
- *Environmental Systems Analysis* – The research is concerned with the development, use and evaluation of methods and tools for environmental assessment of technical systems. The role of such methods in decision-making, management and communication is another research theme. The relationships between different tools (differences, similarities, shared data sets, information flows between tools etc) are also subject to research.

COMESA is responsible for the master's programme Civil Engineering and Architectural Management.

#### STRUCTURAL ENGINEERING AND MECHANICS

Research groups:

- *Mechanics* - Structures and materials are modelled and simulations are made to investigate the effect of mechanical and environmental loads. The research is concentrated on computer-based analyses of a variety of engineering pro-

blems. In particular, the Finite Element Method (FEM) combined with modern techniques for visualisation is used.

- *Concrete Structures* - The research deals with the load-carrying capacity, stability and functional design of concrete structures. Advanced fracture mechanics analysis models are developed and used together with laboratory experiments resulting in a better understanding of the mechanical behaviour and function of concrete structures.
- *Steel and Timber Structures* – The research areas are quality and mechanical properties of timber, load-carrying capacity of timber and steel components, strengthening of steel members with advanced composite materials, fatigue of steel structures and applications of CAE in structural engineering.

The Department runs the master's program Structural Engineering.

#### GEO-ENGINEERING

Two research groups are organised at the department:

- *Engineering Geology* – The main research focus is on hydrogeology and its implications for water supply, the underground environment and underground construction. Another theme is research on aggregates.
- *Geotechnical Engineering* - Stress-strain properties of soil and rock, soil and rock mechanics and foundation engineering. Areas of special interest are slope stability, pile foundation, soil stabilization, earth pressure on buried rigid pipes, statistical methods in geotechnical engineering.

The Department is responsible for the master's program Geo-environment and Infrastructure.

#### WATER ENVIRONMENT TRANSPORT

Research themes are:

- *Sustainable Aquatic Systems and Sanitary Engineering Systems* – Research on drinking water, urban drainage, sewage water and sewage systems. Environmental Measurement Techniques is an important research area.
- *Waves and Fluid Mechanics* – Research on wave energy, waves from fast ships and 3D-analysis of water currents for sanitary engineering.

The Department is responsible for the planned master's programmes Environmental and Infrastructural Engineering and the existing programme Applied Environmental Measurement Techniques.

## Centres at the School of Civil Engineering

- Centre for Management of the Built environment
- Centre for Structural Design
- Mistra Urban Water

Research groups from the School of Civil Engineering also takes part in CHARMEC, which is a Centre of Excellence, or Competence Centre, in Railway Mechanics and in CPM, which is a Competence Centre in Environmental Assessment of Product and Material Systems.

## Some Basic Figures of the Departments Involved

Department	Applied Acoustics	Building Technology	COMESA	Structural Engineering and Mechanics	Geo-Engineering	Water Environment Transport
Total number of employees	19	43	30	45	27	26
Professor	2	3	2	4	3	3
Adjunct professor	1	1	1	2	2+doc	-
Guest professor	-	-	2	-	-	1
Associate professor	3	2	3	5	1	
Senior lecturer	-	-	-	-	-	-
Lecturer/docent	-	4	3	4	1	2
Researcher	1	3	3	10	3	4
Guest researcher	-	-	-	1	-	-
Technicians	1	5	-	2	5	1
Administrative personnel	1	3	3	3	2	3
PhD. students (employed)	9	11	10	9	4	10
PhD students not employed with an activity more than 50%	1	11	3	5	5	1

*Detailed description of different categories employed at the departments in the School of Civil Engineering. 2004*



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## Appendix 3.

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# Lund Institute of Technology (LTH)

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The Engineering Faculty, also called Lund Institute of Technology (LTH), is a part of Lund University. LTH was established in 1961 and is Sweden's third largest unit for research and higher education in the technology field. Undergraduate teaching and research are pursued in the fields of chemical, environmental, civil, mechanical, electrical and computer engineering, as well as engineering physics, industrial management and engineering, risk management, architecture, industrial design and surveying.

### Education

The total number of students at LTH in year 2002 was 5.409 (full time equivalents). The majority of these (4.421) follow educations of master type. The rest is bachelor type education at Campus Helsingborg (490) and continuing education (498). Some student data for educations related to the built environment are given in the table below. An international masters program "Water Resources" for 30 students started in September 2003.

Education program	Students, full time equivalents		Exams	
	2002	2001	2002	2001
Civil Engineering	407	385	73	69
Architecture	297	271	48	46
Surveying	157	148	20	16
Environmental Engineering	189	158	4*	0*
Fire Safety Engineering	154	142	32	21

\* New program

*Key figures for education programs at LTH related to the built environment*

## Personnel

The total number of employees 2002 at LTH was 1.569, distributed as shown in the table below.

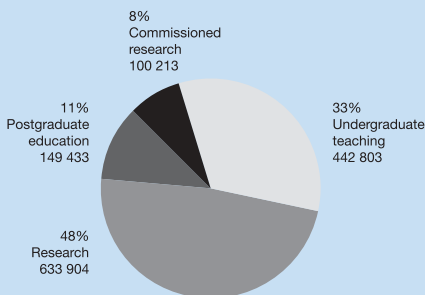
Category	Number	(%)	Women %
Academic staff	553	(35)	20
PhD-students	534	(34)	28
Administrative personnel	225	(14)	77
Others, research engineers, technicians, etc.	274	(17)	26
<b>Total</b>	<b>1569</b>	<b>(100)</b>	<b>30</b>

*Employees at LTH 2002*

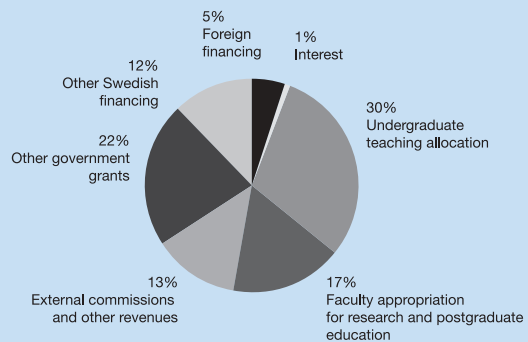
LTH had 160 professors 2002, compared to about 90 in 1999. The increase is mainly due to promotion of academic staff already employed at LTH.

## Economy

The total turnover 2002 was 1.287 MSEK. The expenditures were distributed according to Figure 1. The distribution of income sources is shown in Figure 2.



*Figure 1. Expenditures at LTH, 2002, kSEK*



*Figure 2. LTH:s income sources, 2002*

Figure 2 shows that the direct government allocation of resources to LTH amounts to 47 percent of the total income. The rest is external funding from various sources. For example, the income from individual Swedish companies 2002 was 104 MSEK. The income from EU research funding was 42 MSEK, whereas the income from Formas was 25 MSEK.

## Organisation

LTH is part of Lund University and constitutes its Faculty of Engineering. Its departments carry out teaching and research, and postgraduate education is pursued in all areas. Undergraduate teaching is mainly organised according to programmes, each governed by an undergraduate programme board. Three research boards covering the areas perform quality assurance as well as strategic planning and evaluation of research activities at LTH.

- Chemistry and Chemical Engineering
- Physics, Informatics, Mathematics, Electrical Engineering (FIME)
- Mechanical Engineering, Civil Engineering, Architecture & Design (MVA)

The LTH Board and undergraduate programme boards include professional representatives from outside LTH. LTH, including the School of Engineering at Helsingborg, has 22 departments with 80 divisions, and over 40 multidisciplinary centres.

Out of the 22 departments, the following four departments concentrate on research dealing with technology and architecture for the built environment.

- Architecture
- Building and Environmental Technology
- Construction and Architecture
- Technology and Society

In economical terms (income 2002) these four departments constitute 18.3 percent of LTH. (16.8 percent of LTH:s total government funding and 19.7 percent of the total external funding to LTH)

## Research Related to the Built Environment

The research at LTH as a whole covers a very wide range of fields within science and engineering. In a broad sense the following major research areas can be identified:

### *Applied areas*

- Communication and Information Technologies
- Biotechnology and Genetic Engineering, Food and Food Engineering
- Environmental and Energy Engineering
- The Built Environment - Engineering and Architecture.

### *Methodological areas*

- Complex Systems and Mathematical Image Processing
- Nanoscience and Advanced Measuring Techniques
- Production Techniques and Industrial Design

A more detailed account will be given here of the research and competence structure related to the Built Environment. This area deals with the physical infrastructure on the dimensional scale Region ? City ? Building ? Materials and Technology. Another dimension is the scale from Basic to Applied research. We believe that it is important to have an appropriate balance in the competence structure related to these two dimensions. LTH:s major research units, within the four departments mentioned above, and their position on these scales are indicated in Figure 3.

## **School of Civil Engineering**

### DESIGN AND CONSTRUCTION OF BUILDINGS

The competence structure within the field of Civil Engineering at LTH is to a large degree profiled towards design and construction of buildings. Significant ongoing research deals with indoor environment and energy efficiency in buildings. The Foundation for Development of Knowledge and Competence (KK-stiftelsen) and Swedish industry sponsor a large graduate school The Building and the Indoor Environment with 18 PhD-students from industry. There is also research with focus on energy use, passive and active solar design, daylight utilisation and shading of buildings. Research and technology transfer regarding moisture safe design and construction is performed in the framework of the Moisture Research Center at LTH.

Further-more, significant research is focussed on productivity in construction through increased efficiency in the building process and optimisation of building systems with respect to all significant aspects. LTH is host organisation for the graduate school Competitive building financed by the Swedish Foundation for Strategic Research (SSF) and the building industry. Information management in the building process is one important area of research, which is co-ordinated in the Centre for Information Technology in Construction and Facility Management (CITS).

### MATERIALS AND STRUCTURES

In the field of materials and structures, LTH has a special competence concerning durability, in particular for concrete and

masonry. Pioneering work has been done at LTH in the modelling of fracture processes in concrete and wood. LTH has research groups in the fields of wood science; timber engineering and mechanics for fibre based materials and a high competence in structural reliability as well as advanced numerical analysis in structural and solid mechanics.

WATER RELATED RESEARCH

LTH water related research consists of hydromechanics, coastal engineering, hydrology, physical limnology and hydro-meteorology. Specialised areas within hydrology include surface hydrology related to snow and ice as well as in semi-arid climate, and forestry as well as agriculture, urban storm drainage and geohydrology. There is also a division for water and sewage engineering. The water related research is strongly focussed on environmental issues. One division does novel work within applied geo-physical measurements and environmental geo-technical engineering.

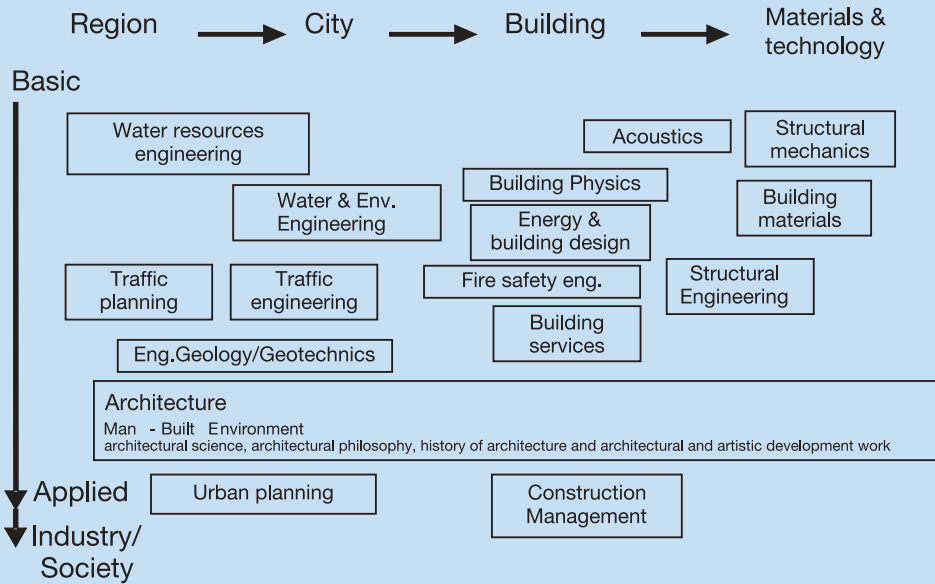


Figure 3. Competence structure related to the built environment

TRAFFIC PLANNING AND TRAFFIC ENGINEERING

The research of traffic planning and traffic engineering deals with planning, design and management of traffic systems, in consideration of requirements from traffic, from residents in the vicinity and from the society. The most important governing factors are traffic efficiency, safety, environment and transport economy. There is also a group dealing with highway engineering.

#### FIRE SAFETY ENGINEERING

LTH is one of very few universities in Europe with significant research in fire safety engineering, and has one of very few undergraduate programs for fire safety engineers in Europe. Research includes combustion processes, fire development and spread in buildings, extinguishment and analysis of fire related risks in industrial facilities as well as in commercial and residential buildings. Presently, the activities develop in the direction of more general risk management; co-ordinated through Lund University Center for Risk Analysis and Management (LUCRAM), which was established about ten years ago.

#### ARCHITECTURAL RESEARCH

Architectural research at LTH includes architectural science, architectural philosophy, and history of architecture as well as architectural and artistic development work.

Research concerning the relation man-built environment aiming at a sustainable society characterises the architecture departments. The research is both substantial and methodological, including theoretical and empirical studies. Research in environmental psychology, studying among others effects on humans by colour and light in the environment, is of highest international recognition. Participatory design, housing for elderly, and full-scale laboratory studies of work environments are established fields. Architectural design for indoor climate and energy-efficient building is an important research area.

Other research fields are history of architecture, building conservation and restoration, architectural philosophy and design methodology. Studies of consequences of information and communication technology (ICT) for design processes and for living and working environments are well developed. Urban design studies concern for example design methods, urban typologies, territoriality and identity, public space and green areas. Housing and settlement studies in developing countries have a long standing tradition. Specific mention should be given to the international masters education in housing development and management for students from developing countries.

## **Built Environment: list of research units at LTH**

### **Department of Building and Environmental Technology**

- Building Physics
- Building Materials
- Engineering Acoustics
- Engineering Geology
- Fire Safety Engineering
- Structural Engineering
- Structural Mechanics
- Water and Environmental Engineering
- Water Resources Engineering

### **Department of Construction and Architecture**

- Architecture and Restoration
- Building Services
- Construction Management
- Computer Aided Architectural Design
- Housing Development and Management
- Energy and Building Design

### **Department of Technology and Society**

- Traffic Engineering
- Traffic Planning
- Highway Engineering

### **Department of Architecture**

- Architecture – Building Functions
- Architecture and Development Studies
- Environmental Psychology
- History of Architecture
- Theoretical and Applied Aesthetics
- Urban Planning



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## Appendix 4.

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# Luleå University of Technology (LTU)

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Luleå University of Technology provides education and research in two faculties; Arts and Sciences and Engineering - Together they cover the following 11 spheres: Engineering, Social Sciences, Humanities, Teaching, Health Sciences, Music, Media Education and Drama. The University has about 12,500 students enrolled and a staff of 1,500. The campuses are located in Luleå, Piteå, Kiruna, Boden and Skellefteå. The University has three main tasks: undergraduate education, research/postgraduate education and co-operation with other sectors of society.

### **The Budget for 2002:**

- Total turnover 1.101 MSEK;
- Research 536 MSEK including 310 MSEK of external funding.

### **Research Degrees:**

- 2000: 40 PhD (10 women); 61 Lic. (21 women)
- 2001: 43 PhD (11 women); 70 Lic. (18 women)
- 2002: 50 PhD (13 women); 68 Lic (19 women)

### **LTU:s Spirit**

The Luleå spirit is a question of originality and inventiveness – important qualities for a university situated on the fringes of Europe, far away from the old prestigious universities and cities with a long academic history.

To put it simply, one can say that the Luleå spirit is about taking the lead. Being the first to think in an innovative way and daring to test new and modern solutions which meet the need of companies and society for competence, and which give students a sound foundation for a long professional life with many changes. The aim is a modern and up-to-date undergraduate education and research better suited to the complex knowledge-based society of today. The University's co-operating partners among companies and in the surrounding society have an important role in this development work.

## **Vision**

*“We will strive to be a leading national university with an international reputation. Each student, faculty and staff member will feel a sense of enthusiasm and strive to attain excellence.”*

## **Mission Statement**

*“We interact with society to bring forth and convey knowledge and learning in the areas of engineering, teaching and learning, the social sciences, the humanities, music and drama. We place scholarship and the student in focus. Our activities are based on science and the proven authority of experience. We work with an interdisciplinary approach in close-unit community.”*

## **Faculty of Engineering**

The following disciplines compose the research profile: Mechanical Engineering, Materials Technology, Human Work Sciences, Wood Technology, Civil Engineering, Environmental Engineering, Mining, Metallurgical Engineering and Process Engineering.

The main research areas at the faculty of Engineering are the following:

- *Product Engineering and Manufacturing*  
Research in this field mainly concerns the manufacturing industry.
- *Infrastructure and Engineering*  
Civil engineering, environmental engineering, communications and cold climate engineering
- *Resources and Environmental Engineering*  
Applied research in ecology and environmental conservation; the development of better methods of chemical analysis, environmental monitoring, land remediation and landfill technology
- *Process Engineering and Automation*  
The research is focussed on the extraction and processing of raw materials and residual products; minerals and lumber.
- *Distance-spanning Information Technology*  
Research on tele-traffic and communication systems, radio systems engineering, data transmission and information theory

- *Technology, Man and Organization*

Examples of research fields are the working environment, management, gender and technology, running small businesses from a regional perspective and quality technology.

**Research Degrees:**

- 2003: 29 PhD (5 women); 56 Lic. (20 women)
- 2004: 36 PhD (7 women); 68 Lic. (17 women)
- 2005: 41 PhD (8 women); 60 Lic (15 women)

**Department of Environmental Engineering**

Turnover (2002): 70 MSEK, of which 51 MSEK on research and 19 MSEK on education. 33 MSEK of research was external funds.

Examinations (2000-2002): PhD 16; Lic. 27.

The *Vision* of the new Department is to contribute to a sustainable society by:

- Carrying out vital research programs in our special fields of strength in close co-operation with industry and society.
- Giving students an excellent learning environment. Our seven months trainee period is unique in Swedish M Sc Programs.
- Minimizing administration

**Divisions:**

WASTE SCIENCE AND TECHNOLOGY (WST)

The division performs research on a variety of aspects on waste management such as: generation, collection, treatment and disposal (including recycling) of waste materials. The aim of the research is to develop tools for a sustainable waste management. The division has received one research project from BFR/Formas – Bottom ash in road construction – and the project is included in the special research area Ground and Water in the City.

RENEWABLE ENERGY

Thermal energy storage, in particular seasonal storage of heat and cold, has for a long time been the main field of research. This includes research on borehole storage systems and borehole systems for extraction of heat and cold from the ground. Presently ongoing projects, includes storage systems for space

heating and space cooling, a water-driven drilling method for drilling of geothermal wells, thermally driven groundwater convection, seasonal storage of snow, thermal response test in boreholes, and condensation irrigation. The division has presently seven employees, five PhD students and two professors. Professor Bo Nordell is the head of this new division, which started on the 1st Jan 2003. the Swedish Energy Agency (STEM), Formas, and the Swedish International Development Agency (Sida) finance ongoing research.

#### GEOGRAPHIC INFORMATION TECHNOLOGY (GIT)

The division performs research on Mobile Systems, Information Support and Data Quality.

Research areas:

- Mobile Systems;  
Problem fields: Data collection in field, decision support in field, architectures for dynamic networks.
- Information Support;  
Problem fields: Introduction of standards, linked and value adding services.
- Data Quality;  
Problem fields: Estimation of quality measures, judgement of applicability, development of components for quality judgement.

#### APPLIED GEOLOGY, APPLIED ORE GEOLOGY AND APPLIED GEOPHYSICS

These divisions perform research regarding environmental geology, analytical geo-chemistry, hydrology and ecology. They are also profiled towards the geology of mineral and metal resources and economic geology, i.e. the understanding of where and how economic concentrations of metals and minerals occur.

#### TRAFFIC ENGINEERING

The research is focused on traffic safety and physical planning. The research in Traffic Safety especially concerns pedestrians and cyclists. The weakest road users, children, elderly and disabled people are specially observed. Anti-slip devices for pedestrians are also studied. Accessibility for different road users in urban areas is analyzed. The research in Physical Planning focuses on planning processes and planning tools to achieve the sustainable society. Planning indicators for energy planning and mobility in urban planning are the subject for the research.

#### SANITARY ENGINEERING.

The challenge of improving the sustainability of our society is of great importance to the Division, as well as to supply competence to the water industry. During 1993-2002 the Division has received grants from BFR/Formas for 3 research programs and 2 projects (7.2 MSEK). 4 PhD and 6 Lic. Exams were the outcomes from this research.

#### WATER RESOURCES ENGINEERING

The dominating support from BFR/Formas to the division was for energy-related research – thermal energy storage. The research is now located to a new division, Renewable Energy Systems. Research, outside the energy sector, carried out at the division was partly supported by BFR/Formas during 1993-1998 through a frame program headed and administrated by the Division of Sanitary Engineering – atmospheric icing and snow melt. The division is also involved with project in the BFR/Formas special research area: Ground and Water in the City.

### **Department of Civil & Mining Engineering**

Turnover (2002): 70 MSEK, of which 51 MSEK on research and 19 MSEK on education.

35 MSEK of research was external funds.

Examinations (2000-2002): PhD 11; Lic. 23.

#### **Divisions:**

##### CONSTRUCTION MANAGEMENT

Research within the division is mainly divided into three areas:

- Organisation and management
- Production process
- The client's role.

The division is also involved in the two national projects Competitive Building and Competitive Infrastructure

##### ROCK MECHANICS, MINING ENGINEERING

Research in the divisions is going on in the following areas:

- Fracture process in rock
- Rock fragmentation
- The influence of the loading route on the fracture process
- The strength of rock masses
- Strengthening of rock with sprayed concrete

- The state of stress and its influence on the stability of rock
- The behaviour of rock after blasting
- Ice in tunnels
- The blasting process
- Efficiency of various explosives
- Ballast for road building and concrete production

In 2003 a new centre Swedish Blasting Research Centre (Swebrec) was formed at Luleå University of Technology. The personnel consist at present of four senior research engineers. The mining, mining equipment and explosives industry, supports the centre. It was earlier a part of Swedish Rock Engineering Research (SveBeFo).

#### SOIL MECHANICS AND FOUNDATION ENGINEERING

The division are focused on research projects with the following themes:

- Geotechnical engineering for cold regions
- Environmental soil mechanics
- Organic soils- including sulphide rich soils
- Coarse materials
- Advanced calculation methods

#### OPERATION AND MAINTENANCE

The division covers areas of:

- Maintenance analysis
- Reliability and maintainability analysis
- Product Support
- Condition monitoring and condition based maintenance
- Maintenance performance measurement system
- Life Cycle Costing (LCC)
- Maintenance
- Maintenance product support
- Reliability Centred Maintenance (RCM)
- Total Productive maintenance (TPM)

#### STRUCTURAL MECHANICS

The division deals with several projects/problems on the development of programs based on the finite element method for non-linear applications in structural mechanics. New codes for finite element calculations has been developed and compared to existing standard codes. The division has international collaboration with at first hand Norway and Poland. The different areas include:

- Improved mixed finite elements – basic research
- Ice structure interaction and improved modelling of ice – applied research with local interests
- Solution methods for non-linear static and dynamic problems – basic research
- Cracks and Inner Softening Bands – applied research
- Material and Structure interaction in Silos – applied research with local interests
- Hydroforming – applied research

#### STRUCTURAL ENGINEERING,

Research is focused on efficient and effective design, production and maintenance of structures for a sustainable society. The research at the division is mainly focused on the following six research areas:

- General Structural Engineering and Fracture Mechanics in Mature Concrete
- Young Concrete behaviour – crack risk, shrinkage creep
- Centre of High Performance Cements – new environmental friendly binders
- Assessment, Repair and Maintenance of Concrete Structures, especially with Carbon Fibre Reinforced Plastics (CFRP)
- Port and Ocean Engineering under Artic Conditions – ice forces
- Centre for Information Technology in Construction

#### STEEL STRUCTURES

The basic aim of the research is that it shall give a substantial contribution to a better building process through better and less expensive design solutions and production methods. The core of the research is steel structures in a broad sense such as stability, welded and bolted connections, thin plate structures, light gauge framing, composite structures, pressure vessels and material modelling. The applications are on normal and high strength carbon steels as well as stainless steels. In this area the division works internationally and is involved in the development of the Eurocodes. Beside this, the division is involved in IT-based design support, the building process including procurement and tendering in construction, environmental aspects of construction, risk and safety from an environmental and structural perspective.

#### TIMBER STRUCTURES

The vision for the division is to make industrial timber construction competitive on the market. The mission on the way

is to make wood the most interesting building material by adding knowledge and skill. The division should stand for: evolvement of research across the sciences, reliability and curiosity.

There are several Centres in the Department:

- *Ebygg* – A Centre for Information Technology in the Building Sector, specializing in planning and design in four dimensions; (length, width, height, time; 4D).
- *JvTC* – Centre for Railway Engineering Research, specializing in maintenance of rolling stock track
- *Coldtech* – Centre for Cold Climate Technology, specializing in freezing and thawing of soils, ice mechanics and housing in cold climate.
- *CHPC* – Centre for High Performance Cement, specializing in Energetically Modified Cements, i.e. cements grinded together with quartz sand, blast furnace slag or fly ash to reduce energy use and carbon dioxide emissions of ordinary cement clinker
- *Swebrec* – Swedish Research Centre for Blasting at Luleå University of Technology, see above under Rock Mechanics, Mining Engineering.

### **New Department – Civil and Environmental Engineering**

The Department will be established in January 2004 mostly by merging the Departments of Environmental and Civil and Mining Engineering. 130 people will work in this new Department. There will be two Special areas (Arenas) for Teaching and Research:

- Global Resources
- Risk and Safety

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## Appendix 5.

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# Swedish National Testing and Research Institute, SP

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### The Research Institute SP

Swedish National Testing and Research Institute (SP) is one of the biggest research institutes in Sweden. With a multi-disciplinary approach the aim is to contribute significantly to innovation and growth in industry and to sustainable development in the society as a whole. SP is a national institute with a comprehensive competence in a number of profile areas such as Building, Energy, Fire and fire protection, materials, Transport, Electronics, Measurement techniques. SP is a company owned by the Swedish state with 550 employees in total. Employees dealing with Building and Construction issues in the broader sense are approximately one third of the total number.

### Vision and Mission

SP: s vision is to be a leading international research and technology organisation of key importance for competitive industry and for sustainable development in society. And its mission is to enhance development and competitiveness of industry and business and safety, good environment and sustainable development in society. The means are research and development, technical evaluation and measurement technology. Basics are competence, efficiency, impartiality and national and international acceptance.

### Strategies

SP uses the three steps development, application and dissemination of knowledge in a systematic way, for interaction, influence and feedback concerning all parties involved. Which also means that SP participates in all the steps from research to industrial applications, which enhances knowledge transfer. Multi-disciplinarity is utilized to combine competencies for attacking new problem areas in industrial branches or societal areas. Examples can be found in the building and energy areas, where e.g. material science and chemical analyses are combined

with knowledge in thermodynamics, building physics and structural mechanics etc. SP is actively cooperating with universities, institutes, industry, users and various organisations in politics and society. More than 90 projects are carried out in close co-operation with different departments at Swedish universities and university colleges. Co-operation is mostly concentrated to Chalmers, KTH and LTH.

SP puts the "Triple helix" -concept into practice. This is essential for SP as an efficient contribution to the growth of the innovation system. High priority is also given to international co-operation e.g. in EU-projects. This is important for exchange of knowledge, influence and creation of confidence and networks facilitating trade and increasing competitiveness. All SP staff members have a wide co-operation in research and a strong international network. SP is strongly involved in activities in organisations as Eurolab, Euromet, ENGOLF (fire), ENBFRI, RILEM, IABSE, CIB (building), Eurachem, ENCRESS (software), ADLNB (telecommunication), EMCIT/EMCEL (electronics), CEEES (environment), IEA (energy), ESIS (mechanics) and VAMAS (materials).

### **Organization**

SP is a national institute with a comprehensive competence in a number of profile areas such as Building Technology and Mechanics, Chemistry and Material Technology, Energy Technology, Fire Technology, Electronics, Measurement Technology, Weights and Measures, and Certification.

### **Work Principles**

Many staff members have specialist or area responsibility and close market contacts. SP has about 8000 customers and other contacts annually, mostly with small and medium sized enterprises, which results in many networks and brings experienced project leaders. The development of SP:s personnel is made systematically and followed up for all kind of personnel, as well in Ph D, graduate and under-graduate courses as in special courses and in planned participation in R&D. SP has a management system integrating requirements for laboratory work (ISO 17025) and environmental management (ISO 14000). There are special routines for the planning, performance, reporting and evaluation of R&D. SP uses the technique with balanced scorecards in order to run a complex organisation with multi-dimensional goals successfully. Aims and vision are made measurable in terms of aims in four "dimensions" (economy, customers, competence and processes), which balance

each other. SP is project oriented and all activities are run as projects supported by a modern business/economy system. All personnel declare time spent on projects. This means that all costs and incomes can be related to the performance of a project. SP has an integrated plan and a policy for equality between sexes and for non-discrimination according to Swedish law.

## **Organisation of Research on Building and Property Management**

Research and development related to Building and Property Management is one of SP:s key areas characterised by a wide technical span including sustainable development, indoor environment, building acoustics, efficient production and use of energy, materials and construction technique, wood and wood technology, fire, productivity and operation and maintenance. The research activity becomes more and more international. SP participates normally in about 20 projects dealing with construction and buildings within the European framework programmes and co-ordinates some of them. In order to co-ordinate the activities related to construction there is an internal network, the SP Group for Building and Property Management, and the following important research areas are to be found within this network:

- Concrete and Concrete Technology
- Wood Materials and Structure
- Geological Materials
- Thermal Insulation and Air Tightness in the Building Envelope
- Moisture Control and Indoor Environment
- Acoustics
- Fire Response of Building Materials and Structures
- Spread of Fire Effluents and Environmental Impacts
- Polymeric Materials
- Service Life Prediction of Solar Thermal Components
- Coatings and Surface Protection
- Building Materials and Indoor Air Quality

Today 11 PhD students, which are employees of SP, are active in the 12 research areas. Their projects are done in co-operation with a Technical University. During the last ten years 9 employees have got their licentiate and 6 employees their PhD in the field of Building and Property Management. In addition to this, 13 students from abroad have carried out their Master thesis work at SP, all of them in the field of wood technology.

## Financing

Many of the R&D activities at SP are co-financed, and SP receives in competition grants from about 20 of the Swedish research councils, funds and authorities. This financing has increased considerably during the last decade, while the government grants for development of new knowledge through R&D have decreased slowly. The governmental grants were about 9 percent of SP:s total turnover in 2002.

<b>R&amp;D</b>	Industry (full financing)	39
	Industry (co-financing.)	7
	R&D financers	24
	Authorities	17
	International	16
	Government	40
	Total	143
<b>Services</b>	Industry	257
	Government	13
	Total	270
<b>Dissemination of knowledge</b>	Industry	10
	Government	6
	Total	16

*Financing in MSEK 2002*

## Research Environment

SP is a company owned by the Swedish state with 550 employees including 75 PhD, 25 licentiates, 140 Masters degrees and a number of BSc. This means that the technical areas/environments at the departments in general have a sustainable research competence and capacity for the tutoring of PhD students. The number of researchers in the field of Building and Property Management at SP are 37 including 32 PhD and 5 licentiates. Among the researchers are one professor and 5 adjunct professors. The number of employees dealing with Building and Construction issues in broader terms is approximately one third of the total number.

### Facilities:

- Fire research facility
- EMC research facility)
- National metrology institute (synergy with experiments)
- Surface and materials analysis  
(Co-operation with Chalmers)
- Shock, vibration and fatigue with high capacity

- Advanced numerical simulations (CFD, FEM etc) in combination with full scale experimental validation
- Sustainable groups of researchers who can make efficient and scientifically advanced use of equipment

### **Knowledge Dissimination 2002**

- 230 reports and articles
- of which 94 with peer review
- 270 lectures/presentations
- 150 seminars, meetings an courses
- “Thousands of customers”







Formas, the Swedish Research Council for Environment, Agricultural Sciences and Spatial Planning, is a governmental research-funding agency. Formas encourages and supports scientifically significant research related to sustainable development.



Forskningsrådet för miljö, areella näringar och samhällsbyggande, Formas  
*The Swedish Research Council for Environment, Agricultural Sciences and  
Spatial Planning*

Box 1206, SE-111 82 Stockholm, Sweden. Visitors: Birger Jarls torg 5  
Phone: +46 (0)8 775 40 00, Fax: +46 (0)8 775 40 10  
E-mail: [info@formas.se](mailto:info@formas.se), [www.formas.se](http://www.formas.se)