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Evaluation of Civil Engineering Programs at Swedish Universities and Institutions of Higher Education

HÖGSKOLEVERKET
Swedish National Agency for Higher Education

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Summary

This evaluation concerns the eleven Swedish universities and higher education institutions (HEIs) with civil engineering educational programs. The evaluation has been conducted by a panel of external evaluators and is based on an approach that the panel has defined in consultation with the concerned HEIs and a selection of interested parties. Each HEI and the educational programs have conducted a self-evaluation, and these, together with a discussion with groups during a site-visit, form the basis for the evaluation. Based on this data, the evaluation panel has drawn the conclusion that the quality of Swedish civil engineers is good and that they have the ability to compete internationally. The panel is of the opinion that the civil engineering programs are good but can be improved. The programs should be expanded to five years.

Training in engineering and natural sciences is generally sufficient, but social, economic and environmental applications of engineering are poorly provided for. Dialog with future employers should be improved and there should be more work practice than there is now.

Faculty qualifications are strong, especially research qualifications, but faculty members are hard pressed. They are forced to use their free time and research time for teaching.

There are shortcomings in the administration and management of the educational programs in that responsibility and authorization are not always in line. A systematic and holistic approach to quality assurance is missing, on the whole.

The HEIs have good internationalization activities. However, too few students take advantage of the opportunity to study abroad. Conditions for receiving foreign students are good at most programs.

The percentage of women of students who begin a civil engineering program has decreased. This is not only a matter of recruitment, but also of teaching methods and educational culture.

The civil engineering education has expanded dramatically with four new HEIs and a large number of programs. At the same time, the number of students seeking admission has decreased, despite major recruitment efforts. Several learning environments are currently small and vulnerable and there are no mechanisms for obtaining a realistic volume of civil engineering education. The students take a long time to graduate and the HEIs lack sufficient systems for monitoring and increasing throughput. The economic management of HEIs does not reward the right things. There should be incentives for the HEIs to specialize, to invest in the types of education that the labor market needs, and to get the students to complete their studies within a normal period of time.

The report begins with the Swedish National Agency for Higher Education's decision and observations. This is followed by the evaluation panel's report.

A note to the English edition

Throughout this report, the term civil engineer is used as a translation of the Swedish word *civilingenjör*, to denote the profession and training that is evaluated. Civilingenjör is sometimes translated by *Master of Science in Engineering*. In Sweden, however, these are two different degrees: a civil engineering degree, while maintaining a high academic standard, is broad and integrates the training of professional skills. A Master of Science in engineering, on the other hand, mainly consists of in-depth disciplinary studies.

Decision

The Swedish National Agency for Higher Education finds that the civil engineering education at Blekinge Institute of Technology, Chalmers University of Technology, Karlstad University, the Royal Institute of Technology, Linköping University, Luleå University of Technology, Lund University, Mid Sweden University, Mälardalen University, Umeå University and Uppsala University meet the level of quality for higher education. The Swedish National Agency for Higher Education, therefore, does not question the entitlement to award degrees at any of these HEIs. This evaluation will be followed up after three years. At the follow-up, the Agency will particularly examine the measures taken by the HEIs to fulfil the second objective of the Degree Ordinance for the degree of Master of Science in engineering (civilingenjörsexamen).

The decision in this matter has been made by the University Chancellor Sigbrit Franke in the presence of Project Manager Aija Sadurskis, Department Head Clas-Uno Frykholm and Administrative Director Lennart Ståhle.

Sigbrit Franke

Aija Sadurskis

Observations of the Swedish National Agency for Higher Education

The Swedish National Agency for Higher Education would, first and foremost, like to thank the evaluation panel for the enormous amount of demanding work the panel has put into the evaluation of the civil engineering education. This effort and the commitment demonstrated by the panel have been invaluable to the evaluation. The Agency would also like to thank faculty and students at the evaluated HEIs for well conducted self-evaluations and a great readiness to treat the evaluation as an opportunity to enhance educational quality.

The evaluation has been performed on three levels: nationally, on the HEI level and on the program level. Besides containing conclusions on the national level, this abridged version of the report contains a summary of the evaluation of the HEIs. A longer version of the report (in Swedish only), which is primarily intended for the HEIs, contains more detailed descriptions and assessments of the HEIs and their programs.

Investigators Aija Sadurskis and Carl Sundström from the Swedish National Agency for Higher Education have acted as secretaries for the evaluation panel.

Many good examples

The evaluation panel finds that the standard of graduated civil engineers is good and that the education is of strategic significance for Swedish trade and industry. Swedish civil engineering education is internationally competitive. Chalmers University of Technology, KTH and the Institute of Technology at Linköping University, together with the Massachussets Institute of Technology in the USA, have been the driving forces behind an internationally successful development of engineering curriculums. Infrastructure and equipment in most locations are very good. Successful research creates good conditions for linking education to research, and the scientific qualifications of faculty members is strong in most cases. Not only at Lund University, but also at other HEIs, the teaching skills of faculty members are actively improved. The civil engineering programs at Luleå University of Technology have good contacts with future employers. Consequently, the conclusions of the panel are, above all, intended to improve educational programs that in many ways are already good.

Limits for civil engineering

In its frame of reference, the evaluation panel defines the characteristics of a civil engineer. Some of the programs covered by the evaluation include such a large element of subjects other than engineering science that the question of

what defines a civil engineering program arises. The Swedish National Agency for Higher Education finds that the programs must strike a balance between the need for development and the need for responsible marketing. In pertinent cases, the quality of the program itself is not in question and it is not obvious that the definition of a civil engineer is necessarily such that these programs fall beyond the limits of the definition. The Agency finds that this is a matter for the HEIs and other interested parties to decide, but would like to emphasize that the programs, to be credible, must be based on a definition of civil engineering that is accepted by at least part of the professional body.

Areas for improvement

The evaluation panel has identified areas for improvement at all the HEIs, such as throughput and the workload of the faculty. Many HEIs, for example BTH, would benefit from another model for direction and management. The panel has also identified areas that can be improved in one or more of the programs at an HEI. A few examples are given here. Contacts with future employers can be improved in many of the programs at KTH. Chalmers and Linköping University can improve the formulation of program goals. Uppsala University can enhance the vocational experience of its faculty members, and Mälardalen University can improve the faculty research qualifications in some of the programs. Umeå University can improve the evaluation of entire programs. The infrastructure of many of the programs at Lund University can be improved. *At the three-year follow-up evaluation conducted by the Swedish National Agency for Higher Education, the Agency will examine how the HEIs have handled the suggestions for improvement given by the evaluation panel.*

Requirements in accordance with the Degree Ordinance

A part of the assignment given to the evaluation panel has been to assess the extent to which the civil engineering education at the HEIs meets standards as put forth in the Higher Education Ordinance degree appendix, the so-called Degree Ordinance. The evaluation panel criticizes the HEIs for not fulfilling the second objective of the Degree Ordinance, namely that the curriculum is to provide the conditions for the student to

> "acquire knowledge of and skills in the design of products, processes and working environments, taking into account the abilities and needs of human beings as well as society's objectives as regards social conditions, economy of resources, environment and economy."

The students often have an opportunity to elect courses that can be studied instead of mathematics, the natural sciences or engineering science, and sometimes a few credits are earmarked for such courses. Even when such courses are mandatory, they pertain to only one or a few aspects of *sustainable applications of engineering*. In reality, the students are presumed to learn sustainable applications of engineering through projects based on the needs of future employ-

ers. The Agency cannot be certain that the HEIs ensure that the students actually learn sustainable applications of engineering. *The Agency assumes that the HEIs will take action, and will check action taken at the three-year follow-up.*

Popular areas and faculty qualifications

Enrollment to civil engineering programs has dropped. The evaluation panel criticizes the HEIs for investing in education in areas that are popular at present, or for giving programs new enticing names, to attract greater enrollment. The Agency agrees with this criticism and points out that having faculty qualifications in an adjacent area is not sufficient. One example is Mid Sweden University, which recently started a program in Mechanical Engineering and Design and needs to enhance faculty qualifications in the field of design.

Small educational environments

Of the HEIs that offer civil engineering programs, four have done so a short period of time, at the most since the year 2001. These are Blekinge Institute of Technology, Karlstad University, Mid Sweden University and Mälardalen University. In some programs, only 5-10 students were admitted in the autumn semester in 2004, which makes it difficult to provide teaching in accordance with existing ambitions. The evaluation panel discusses the problems of such small numbers, both from the perspective of a national need to find mechanisms for obtaining a realistic volume of civil engineering education, and from the perspective of the HEIs. The Agency agrees with the evaluation panel's views and confirms that in the long run it is not meaningful to offer educational programs with such low enrollment.

Structural threats to the quality of education

The evaluation panel sees several threats to the quality of education which are of a structural nature and beyond the control of the HEIs. The panel points out that economic policy instruments create significant problems in that decisions on what programs to offer are entirely governed by the hopes of recruiting students. One consequence of this is that the HEIs invest broadly and do not specialize in areas in which they are strong. The evaluation panel discusses ranking the HEIs or educational programs as a way to stimulate specialization and raise quality. The Swedish National Agency for Higher Education sympathizes strongly with the need for specialization and is not opposed to ranking, in principle. This evaluation is, however, one example of how difficult it is to determine which educational programs have the highest overall quality when many different factors are to be considered. Ranking would not have been easy for the evaluation panel even with the enormous amount of information they have had access to, collected with the intention of standardization.

Another consequence of the economic policy instruments is that the link between education offered and the needs of the labor market is weakened. This problem applies to the entire higher education sector. Since the Swed-

ish National Agency for Higher Education has pointed out this problem in many evaluation reports, the Agency has been assigned by the government to submit data for planning realistic volumes of higher education in relation to labor market needs, and to report on this annually. The Agency has, however, in various contexts pointed out that the system of allocating resources needs to be reformed so that it promotes a more desirable development of higher education.

THE EVALUATION PANEL'S REPORT

Main Conclusions and Suggestions

This evaluation was commissioned by the Swedish National Agency for Higher Education and concerns the quality of the 97 civil engineering programs offered in the spring 2004 at the eleven Swedish universities and HEIs that offer civil engineering education. Each HEI as well as each program has conducted a self-evaluation based on questions developed in dialog with the HEIs, the chairperson of the evaluation panel, and the Swedish National Agency for Higher Education. The evaluation is based on a frame of reference defined by the panel in consultation with the concerned HEIs and a selection of interested parties. The evaluation panel has read the self-evaluations and talked to the individuals in charge of the programs, students, faculty, faculty boards (or the equivalent, such as department heads) and directors at site-visits to each of the eleven HEIs. Based on this information, the evaluation panel has drawn the following main conclusions. Additional important conclusions can be found in later chapters, but are not dealt with in this summary. The conclusions are general in nature and exceptions may be found at some of the HEIs.

Quality of civil engineers

The quality of civil engineers who graduate are, in the opinion of the evaluation panel, generally speaking very good, with good and competitive knowledge and skills. Civil engineers are vital to Sweden and Swedish industry. It is very important that the international competitiveness of the civil engineering education is ensured in these times of internationalization and mobility. In light of this, the evaluation panel sees a number of threats that are dealt with below in the section on adaptation to the Bologna declaration.

Formal requirements

The formal requirements in compliance with the Higher Education Ordinance are met with the exception that the education does not provide sufficient opportunities for the student to ”acquire knowledge of and skills in the design of products, processes and working environments, taking into account the abilities and needs of human beings as well as society’s objectives as regards social conditions, economy of resources, environment and economy,” in other words *sustainable applications of engineering*. These areas should be strengthened and integrated into courses and projects.

Educational content

Most of the civil engineering programs have a well balanced and good content, and offer a coherent, integrated education.

The division of courses between basic sciences and technical engineering sciences is generally good. As mentioned above, however, sustainable applications of engineering need to be enhanced. Also, some new programs of narrow scope and some programs which have multidisciplinary instruction with students of natural science, are close to the lower limit in the technical engineering subjects that make it an education in civil engineering.

The evaluation panel would like to see more distinct program goals and closer connections between these goals and course goals, to assure the quality of a coherent, integrated education. It would also enable students to see these connections more clearly and help in their deciding on elective courses.

The quality of education in terms of structure and teaching skills is generally good, in the opinion of the panel. Nevertheless, the panel finds that most programs lack a pronounced strategy for forms for instruction and examination, linking them to the different types of knowledge and skills the program is intended to provide.

Swedish civil engineering education traditionally prepares students for employment, which is, naturally, important. In today's high-tech knowledge society, knowledge and skills in using knowledge to develop new products and services, as well as to develop new companies, is increasingly important. Civil engineering education is a vital part of the Swedish innovation system, and the panel therefore feels that it is important that it provides knowledge and skills in entrepreneurship, and that entrepreneurship as an attitude permeates the education. The panel sees a need to enhance this feature.

Educational quality expressed as throughput

Educational quality is not good in terms of throughput. It takes students too long to finish their studies, and a too small percentage of the students earn a degree. The programs are nominally 9 semesters. After 14 semesters only approx. 55 percent of the students who started a program have earned their degree. Direct explanations for this, according to the HEIs, are that some of the students quit during the first year, which in itself is a serious fault in the education and admission systems; some take a break in their studies, some study abroad for a time and others begin working without having earned a degree.

Reasons for low throughput

The panel can see primarily two major reasons behind the low throughput. One reason is the increasingly varying, and in some students poor, proficiency from upper secondary school in the relevant subjects mathematics, physics, chemistry and languages, and the vast expansion in civil engineering education, with the enrollment of a greater number of students, both factors entailing a need to prolong the studies if quality is to be retained. These changes have occurred at the same time as funding of education has been cut. The second reason is that the current system for allocation of funds only encourages the production of credits, and there is no financial incentive for earning a degree,

for the HEI or the student. The panel notes, furthermore, that the students do not seem to believe or understand that the time they take to earn a degree is a competitive factor. These conditions are, in the opinion of the panel, essentially beyond the responsibility or control of the HEIs.

Measures to increase throughput

In the opinion of the panel there are at least four obvious measures to take to increase throughput:

- Introduce financial incentives for graduating, both for the HEIs and for students.
- Give the relevant subjects in upper secondary education greater weight, by assigning more credits to them than to other subjects when students apply to civil engineering programs, in part to encourage those who study these subjects, and in part to signal that they are vital for the higher education.
- Increase undergraduate funding per student so that the HEIs can take additional necessary action.
- Trade and industry should establish sufficiently large differences in salaries between employees with a degree and those without one, and generally act in ways that encourage students to graduate.

HEIs' handling of changed conditions

The HEIs have, according to the panel, handled the changed conditions, with some of the students less well prepared for higher education and decreased funding per student, well, with a variety of measures, to assure the quality of graduating civil engineers. Many of these changes have had good didactic results in that for instance new forms for instruction has been developed. Other results have been negative, such as larger classes and fewer hours in the laboratory, far too extensive multidisciplinary instruction and, above all, less interaction between faculty and students.

The quality of civil engineers is in danger

The quality of civil engineers, in the current educational system, is threatened. It is the distinct impression of the panel that it has been possible to retain the quality of graduating civil engineers through the great commitment of faculty, but this has been at the cost of the faculty's free time, research and development of their own skills. This is particularly serious, since the faculty, now generally highly qualified, risk losing their research grants and consequently not be able to maintain their level of qualification. Also, there is generally too little time for faculty to develop their teaching skills. The above-mentioned changed conditions are so far advanced that quality is at risk. The panel has the clear impression that the system is over-exerted and that the quality of graduating civil engineers is in danger, if action is not taken.

The civil engineer in the Bologna model

The largest reform that is currently underway in the educational system is the Bologna process. To assure quality and competitiveness internationally, and to assure currency in international education and research, it is vital that the educational program is extended from 180 to 200 credit units, according to the panel. Otherwise, Swedish civil engineers risk being less mobile than those who have studied for their master's degree in other countries. At the same time, it is urgent that the coherent vocational character of civil engineering programs is maintained. It should be possible to have an intermediate diploma or an intermediate leaving system; also, an education in civil engineering should, as it is now, prepare for postgraduate studies.

The evaluation panel suggests that an increase from 180 to 200 credit units is used to:

– reinforce elements of sustainable applications in civil engineering curriculums,
– improve personal and professional skills,
– introduce a requirement for work practice, relevant to each educational program, and awarded credit units,
– reinforce education in entrepreneurship.

Volume of civil engineering education

Civil engineering education has been greatly expanded in recent years in that the number of HEIs that offer programs has increased from seven to eleven. At the same time, the number of students enrolled has decreased, despite major recruitment efforts. Several learning environments are small and vulnerable. It is difficult to obtain an overview of the programs offered, with a large number of 'narrow' programs, i.e., programs with a narrow technical content and/or intended for a limited labor market.

The educational system today is largely governed by students' interests, which is a vital factor but not the only one, since other needs, for example of the labor market, are also important. The panel suggests that an investigation looks into ways of deciding the type of programs to be developed, and the number of students to be enrolled, based on realistic assessments of both student interest and labor market needs (even if the latter vary and are difficult to predict from the perspective of an educational cycle of five years, which in reality is longer). The panel proposes fewer programs, providing a solid and general basis, followed by several electives to form specializations at the end of the studies. This would provide an education that is more flexible, adaptable and accurate in confronting new conditions and needs, which is a vital quality factor in the educational system.

Specialization and ranking

Specialization of the HEIs would, in the opinion of the panel, promote educational quality. It would also strengthen the environments which are cur-

rently too small, strengthen the connection between research and education and probably reduce the number of programs, which is far too large. All the HEIs have high ambitions: to be at the forefront and to be best. Many have set goals with this purpose in mind, but at present there is no way to measure how these goals are met. At the same time, many realize, that they cannot be best in all areas and that they should specialize.

The present system of allocating resources, however, does not promote specialization. It should, therefore, in the opinion of the panel, be reformed, to offer incentives and driving forces for specialization.

In many countries, HEIs and programs are ranked, officially or unofficially. The panel has not taken a position on the suitability of applying such a model to Swedish civil engineering programs. The panel suggests, instead, that an investigation is conducted into whether a ranking system could be used to raise quality, and to provide incentive for strategic choices and specialization.

Internationalization

Internationalization efforts are active at the evaluated HEIs, but far too few students take advantage of the opportunity to study abroad. More effort should be made to convince students of the importance of studying abroad. Since many courses, primarily on higher levels, are offered in English, there are good conditions at most of the programs to admit foreign students. There is, however, a tendency among HEIs and those in charge of programs to underestimate the difficulties of teaching in a foreign language.

Furthermore, the panel believes that the proposed expansion of the civil engineering education to 200 credit units would promote international exchange since the Swedish education would be more compatible with the education in other countries.

The percentage of women who enroll

The percentage of women among students who enroll has dropped. The HEIs see this problem chiefly as a recruitment issue. The panel wishes to point out that it is also a question of teaching methods and educational culture, and hopes to see more of a gender perspective in the activities of the HEIs. The panel feels that the HEIs should take more action and aim more efforts directly at women in the education and research systems to obtain good role models, both as instructors and as researchers. An important example is directed economic support to women at decisive stages in their careers, such as when receiving a PhD or when achieving lecturer competence. In the opinion of the panel this issue must be seen in a larger context and the HEIs, alone, cannot influence and change the sex ratio; efforts should be made on all levels.

Administration and management of the HEIs

Administration and management of educational programs are good at most of the HEIs. There are, however, shortcomings at a number of HEIs in that

responsibility and authorization do not always go hand in hand. A systematic and holistic approach is generally lacking in internal quality assurance. A shortcoming that the panel has noticed is that policies, regulations and procedures are not communicated throughout the organization so that they may be known on all levels. Consequently, it becomes difficult to implement the frequently good ambitions of the HEI leadership. Regarding the evaluation of education, the panel notes that this is readily done on the course level but very seldom from a holistic perspective, on the program level. The panel would like to see a more systematic approach to contacts with future employers; the engineering programs would benefit from a more systematic use of the generally good contacts and research collaboration of the HEIs. As concerns internal economic management, the panel notes that teacher – student interaction is seldom used as a quality parameter, despite its central role for the quality of education. The panel suggests introducing this parameter. The panel also suggests that the HEIs set up concrete objectives for throughput and other results, and develop joint methods for measuring, following up, analyzing and comparing them.

The Evaluation Panel's Grounds for Evaluation and Frame of Reference

The evaluation panel has formulated the following three principles which comprise the frame of reference for the panel's evaluations. See Appendix 1 for a description of the panel.

1. Formal requirements in accordance with the Higher Education Act and Ordinance

The formal requirements on all higher education are put forth, above all, in the first chapter of the Higher Education Act. Requirements for a degree in civil engineering are put forth in an appendix to the Higher Education Ordinance, the Degree Ordinance. These requirements are general in nature and require interpretation.

2. The good civil engineer

In a dialog with the HEIs, the evaluation panel has produced a definition of what characterizes a good engineer and civil engineer, respectively:

Engineers identify the need for and plan, develop, produce, put into operation, utilize and maintain new products, systems or services, as well as close down, recycle or destroy them when they are no longer of use. Engineers are required to have engineering skills, i.e., they are required to act within stipulated financial and time frames to produce sufficiently good solutions to technical problems by applying and retrieving necessary knowledge, and be able to assess and give priority to different technical solutions and work efforts. This work presupposes the ability to co-operate as well as insight into the conditions and needs of people and society.

In addition to this, *civil engineers* must be able to solve research-like and complex problems independently, innovatively and with discernment. Civil engineers are also required to continuously follow, utilize and contribute to the development in their chosen field of engineering.

Civil engineering curriculums comprise engineering science, natural science and other relevant subjects. The studies lead to the profession of civil engineer and are designed on the basis of the requirements of this profession, in consultation with future employers.

The result of a good education is that everyone who earns a degree as a civil engineer

- has the knowledge in mathematics and natural science necessary for their selected field,

- has good knowledge in their selected field of engineering, and specialized knowledge in some part of the field,
- has insight into economic, social and environmental conditions and into needs of coworkers, customers and society,
- has the ability to analyze and critically assess various technical solutions from a holistic perspective, i.e. with understanding of the context in which they are to function,
- can model, simulate, predict and assess events, e.g. mathematically, with computer assistance or experimentally,
- has the ability, after a few years of work experience, to realize products, systems, processes, goods or services throughout their entire lifecycle,
- has the ability to lead and co-operate in projects with different constellations of people,
- has the ability to communicate with other people, with assistance of different media and languages,
- has the ability to utilize their knowledge in other countries and cultures,
- is prepared for life-long learning to be able to adapt to changing conditions for their work,
- has the ability to take responsibility for the impact that engineering activities may have on the environment and on the health and safety of people.

3. Quality and quality assurance

The panel has worked from a broad definition of what constitutes quality in education:

A good civil engineering education is provided when each HEI and educational program has the ability to dynamically and permanently

– train civil engineers in accordance with the above definition,
– adapt the curriculum to new conditions,
– maintain a high rate of throughput and a high level of efficiency, in which both time to graduation and costs for providing the education are important factors,
– continuously improve and develop education.

Evaluated areas

Based on the grounds above, and in consultation with the HEIs, the evaluation panel has agreed that the following twelve areas determine the quality of education provided by the HEIs and their programs. The responses to the self-evaluation questions and the summing-up self-evaluations as well as information from site-visits (see Appendix 1 for a description of the process) constitute the grounds for evaluations of the areas. The twelve areas, which are described in more detail in Appendix 2, are:

1. Direction and management
2. Goals and goal documents
3. Integrated syllabuses
4. Content of programs
5. Deliberate choices of forms for instruction
6. Supportive learning environments
7. Faculty qualifications and teaching skills
8. Examination and degree projects
9. Internationalization
10. Evaluation of programs
11. Flexibility, adaptation, innovation
12. Outcomes, qualitative and quantitative

The evaluation panel has described and assessed each of these twelve areas for each HEI. These descriptions and assessments are available in the full version of the report that can be retrieved from the web site of the Swedish National Agency for Higher Education, **www.hsv.se**. This abridged, printed version of the report contains the most important conclusions for each HEI. Observations and conclusions with national validity will be discussed in the following sections.

The Quality of Civil Engineers

The overall opinion of the evaluation panel is that Swedish civil engineering educational programs, from an international perspective, have produced and continue to produce civil engineers of very high class. The self-esteem of the students is good and they are trained early on in their future profession through the network they are encouraged to build. Also, the HEIs actively strive to improve their programs. Training in giving presentations, both in writing and orally, was previously requested by students and future employers and has now been given significantly more space in the curriculum. One clear example of the Swedish HEIs' international position is that programs [1] at three Swedish universities of technology (Chalmers University of Technology, the Royal Institute of Technology and the Institute of Technology at Linköping University) together with Massachusetts Institute of Technology, MIT, were the driving forces behind what is currently the internationally most interesting development of civil engineering programs, the CDIO initiative (see below in the section Content of education).

Civil engineering students who take part in international work practice within the frame for IASTE[2] receive good recommendations from their employers. In addition, in connection with this evaluation, a number of companies with experience of employing civil engineers from different countries were asked about their impressions. Their responses give a clear picture: Swedish civil engineers assert themselves well or very well both in Sweden and internationally. Swedish civil engineers are said to be very good at applying their knowledge, they are used to working on projects and working and thinking independently. Some characteristics used to describe them are: responsible, open and creative. They are also said to be better at English than civil engineers from other non-English speaking countries. Traditionally, Swedish civil engineers have, above all, been good at practical skills. The training gives students a broad platform and the ability to work in groups which is a prerequisite for modern development work. To quote the person in charge of hiring managers at Ericson both domestically in Sweden and internationally, "A large part of Ericson's success is due to the fact that the technical HEIs maintain such a high level of quality." Civil engineers are of vital significance to Swedish industry.

Nevertheless, the evaluation panel sees a number of factors that threaten this positive picture, as will be discussed in the following sections.

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1. Vehicle engineering at the Royal Institute of Technology, the mechanical engineering program at Chalmers University of Technology, respectively, engineering physics and electro engineering at the Institute of Technology at Linköping University. At MIT it was the Department of Aeronautics and Astronautics.
2. The International Association for the Exchange of Students for Technical Experience.

Requirements according to the Degree Ordinance

According to the Degree Ordinance, an appendix to the Higher Education Ordinance, in order to obtain a degree in civil engineering, the student shall have

- acquired knowledge of mathematics and natural science subjects to the extent required to understand and be able to apply the fundamental aspects of mathematics and natural sciences in the chosen area of technology,
- acquired knowledge of and skills in the design of products, processes and working environments, taking into account the abilities and needs of human beings as well as society's objectives as regards social conditions, economy of resources, environment and economy,
- acquired the knowledge enabling him or her, after a few years' work experience within his/her field, to take independent responsibility for development or utilization of new technology at an internationally competitive level.

In the opinion of the panel, the civil engineering programs satisfy the first and last objectives above. However, the panel sees shortcomings as pertains to the second objective. This objective, for the purpose of this evaluation summarized as *sustainable applications of engineering*, has been neglected in many places. The HEIs waver between offering specific courses, and introducing it as part of a course. Neither of these alternatives seems to satisfy students or faculty. In addition, the focus is generally on one aspect of sustainable application, most often the environment or economy of resources, while other aspects are neglected. The panel can also see that the HEIs have policies for e.g. the work environment and equality, but these are not implemented into the educational program. Upon extending the education, (see below in the section under Bologna adaptation), it is important that sustainable applications of engineering are given more scope.

Content of Education

A review of the evaluated programs shows that they are typically structured so that the first 2–3 years consist of mandatory courses, after which the student has more freedom to choose electives. Each program is made up of a number of courses, some of which are attended by students from other programs, which puts heavy demands on co-ordination, so that course objectives combine to constitute program objectives. The panel can see that many HEIs work ambitiously to create connecting threads throughout the program, but there are also programs that risk falling apart in disconnected courses.

The distribution of courses between basic sciences and technical engineering sciences is good in general in the programs. Nevertheless, the curriculum needs to be reinforced, as mentioned above (see the section Requirements of the Degree Ordinance), in the area of sustainable applications of engineering. The demand for social skills, a holistic view and a humanistic perspective will increase according to the Royal Swedish Academy of Engineering Sciences, IVA[3]. This was also the opinion of future employers and other interested parties at a hearing, held as part of the present evaluation.

The majority of the civil engineering programs have a good content and offer coherent, integrated training in civil engineering. Swedish civil engineering education, however, to a great extent prepares students for employment rather than for entrepreneurship, despite the great significance of entrepreneurship for economic development. The panel finds it important that knowledge of entrepreneurship, and entrepreneurship as an attitude permeate the civil engineering curriculum.

Disciplinary boundaries

A civil engineer is expected to have a broad range of skills with deep technical knowledge of analyzing and synthesizing selected technical areas. To future employers there is a distinct difference between the broad skills of the civil engineer and the specialized skills of mathematicians, chemists, etc. Above all, at the HEIs that have recently begun offering civil engineering programs, enrollment is so low that prospective civil engineers must study in multidisciplinary groups. The panel has seen many examples of courses where different groups of students are taught, and has noticed that this is always motivated primarily by the need to make financial ends meet. The result is a compromise between the needs of two groups of students; the professional profile or the theoretical and technical depth of civil engineering students risk being jeopardized. The

3. *Morgondagens ingenjörer (Tomorrow's Engineers, Swedish only)*, The Royal Swedish Academy of Engineering Sciences.

panel finds this multidisciplinary instruction a potential threat to the quality of the civil engineering curriculum.

The need to define what a civil engineer is has also become greater. Not only has the number of educational programs increased, but so have the types of programs, and there are currently major differences. Demands, in themselves legitimate, that subjects such as economy, leadership, law, etc. be covered, are at the cost of the technical character of the programs. Naturally, the content of engineering science can vary from one program to another, but there must be a reasonable bottom limit. If the engineering science content is small, or large but without depth, can it be called a civil engineering curriculum? It is the panel's understanding that some of the civil engineering programs offered today have reached a lower limit, and that the HEIs should take notice of this.

Engineering fundamentals

The panel frame of reference contains the concept engineering fundamentals: that the engineering curriculum prepares students for solving technical problems within a framework of limits on finances and time. For this reason, a connection to trade and industry is important. The curriculum should be designed in co-operation with trade and industry, and students should have recurrent contacts with trade and industry during their training. The panel finds that these contacts, in many cases, need to be enhanced. Some of the civil engineering programs have few guest lecturers and visiting professors or other faculty from trade and industry, even though permanent faculty members have little vocational experience outside the classroom. The HEIs that have recently started offering civil engineering programs seem to be better in this sense, however. The panel thinks it is unfortunate that guest lecturers are not used more to tie the curriculum to the needs and experiences of trade and industry. The panel also hopes that the HEIs make better use of the generally good research contacts and collaborations. Contacts with trade and industry are not only the responsibility of each HEI; the panel would like to encourage trade and industry to take advantage of all opportunities to participate, contribute and benefit from civil engineering programs.

A committee, assigned by the government to reform education in civil engineering [4], found that the time was perhaps ripe for a more radical reform. In order to improve learning and increase student motivation, theory and practice should be taught together. From the perspective of fundamentals specific to the engineering profession, engineering science terms and explanations would be seen as primary in relationship to natural science. From such a perspective, natural science would be secondary to engineering sciences. The consequence would be that such natural science that is needed to understand topical subjects in engineering are taught then and there. This is a view with which the

4. *Ny ingenjörsutbildning (New Engineering Education, Swedish only)*. Eds. Ingemar Ingemarsson and Ingela Björck, 1999.

panel sympathizes, and which is being implemented at some schools. The CDIO project is a good example of this trend.

An attempt to reform and innovate: CDIO

In recent years, both schools with civil engineering programs and trade and industry have strived to enhance engineering fundamentals and the ability to apply theoretic knowledge of product and system lifecycles. To accomplish this objective, an initiative has been taken by some of the programs at four HEIs: MIT in the USA, Chalmers University of Technology, the Royal Institute of Technology and Linköping University in Sweden. The panel has noticed that the project has begun to spread to other Swedish HEIs and programs, which is positive.

Approximately 20 HEIs all round the world are involved, and more have expressed their interest. The initiative, supported by the Swedish foundation Knut och Alice Wallenbergs stiftelse, is called CDIO – Conceive, Design, Implement, Operate.[5] The model was designed in co-operation with key stakeholders and is intended to be utilized for all types of engineering programs, even if the fields most affected, so far, have been astronautics and aerospace engineering, vehicle engineering, techno-physics, electro and mechanical engineering. The CDIO principle is that engineers work with system and product lifecycles. Since engineers work in co-operation with other people and within a framework of financial and time limits, they are required to have interpersonal and professional skills beyond theoretic knowledge. A CDIO curriculum is characterized by teamwork and co-operation with industry. Subjects are taught in project form to show the interdisciplinary character of engineering, and instruction is based on active learning.

The model also includes processes for evaluation in which students are responsible for self-evaluation and evaluation of each other, and faculty assessment of a student's construction drawings is used as a form of individual examination. By the same token, the CDIO model contains guidelines for continuous improvement of curriculums. Hence, CDIO is systematic quality assurance on the program level.

The CDIO model includes many of the factors that the panel feels are important in training civil engineers of high quality, and that is why it is described in some detail here. CDIO has also been a natural point of departure for this evaluation.

Work practice in the curriculum

Work practice was once mandatory for a degree in civil engineering. The formal reason why this requirement no longer exists is that degree requirements may not include anything other than courses that are awarded credits, and there has been no interest in reducing subject courses to make room for work

5. www.cdio.org

practice within the framework of the curriculum's 180 credits. In addition, the quality of the practice has varied, since it has been difficult to find meaningful work practice placements, owing to a periodically weak labor market.

Practice is important for the quality of studies and thereby for students' employability, as is highlighted in the Bologna process. At the hearing with key stakeholders, including students, mentioned above, it was clearly voiced that a civil engineering curriculum should include work practice, on condition that the practice is relevant and meaningful. This is also desired by trade and industry, as described in reports from the Royal Swedish Academy of Engineering Sciences [6]. The panel has noted that work practice is desired by both HEIs and students, and it is the opinion of the panel that it is vital that meaningful practice is incorporated into the curriculum. Now is a suitable occasion; if the programs are extended with one more semester to be five years (see below in the section The Bologna process), then there will be time and credits for work practice. It is probably necessary to plan for this practice at the same time that the curriculum is expanded, otherwise theoretical subjects will quickly take up the extra time and credits.

Position of mathematics

Mathematics and science are often studied during the first year of the program. The reasons for this are mainly practical. If students are given a joint introduction, then fewer parallel courses are necessary; courses which would be hard to fill and which would require more faculty members. There is also a tendency to see mathematics and science as a platform for coming, applied studies. Obviously, this platform is important, and it is important that students are motivated to learn the mathematics and science necessary for their major. The panel has noted a desire on the part of students to see applications, so that they understand why they have to learn different theories and methods of mathematics and thereby become more motivated. Most stakeholders agree that learning would be improved with another method for instruction. The panel has seen some interesting attempts to deal with mathematics in the context of the technology to which it is to be applied, and recommends that this method is tried on more programs.

Ensuring teaching skills

There is an impressive number of development projects, courses, conferences, workshops, mentors and applied research for faculty members who are interested in teaching issues. Talks with those responsible for the programs, however, reveal a certain resignation towards motivating uninterested faculty members to enhance their teaching skills. Students also describe a reality that is probably very common at HEIs; namely that the teaching skills of faculty members vary much more than their research qualifications, and it is the fac-

6. See *Produktion för konkurrenskraft* och *Morgondagens ingenjörer (Production for Competitiveness* and *Tomorrow's Engineers*, Swedish only).

ulty members who are already skillful who are interested in becoming better. As a certainly unfair comparison, it can be mentioned that MIT, in the USA, requires that faculty members are involved with innovative teaching skill enhancement in order to keep their positions, but MIT has radically different financial conditions than Swedish HEIs.

In their self-evaluation the HEIs have responded to how they ensure the development of faculty teaching skills. Demonstration of teaching skills is generally only required in connection with employment and promotion. Considering the requirements of the Higher Education Ordinance, this must be considered a bottom level. It is the opinion of the panel that the HEIs should act more decisively in relation to faculty members who do not want to develop their teaching abilities.

All of the HEIs offer training in teaching skills. Since this training is general, it does not specifically aim at teaching engineering sciences. Impulses from other disciplines are valuable, but faculty involved in teaching engineering needs to become better at teaching within this area. The panel therefore suggests that the HEIs that have not already done so reform their training in teaching skills so that the training includes elements appropriate to this faculty category.

In talks with faculty and program leadership, the issue of evaluating training in teaching skills was brought up. As in other courses, a course evaluation is common. However, there does not seem to be any evaluation of the results of teaching skill enhancement, i.e. if the participants actually become better instructors. The effect on the outcome of instruction is even less often evaluated: do these teachers' students perform or learn better? The panel suggests that the HEIs evaluate the effects of the resources invested in developing teaching skills more systematically.

Strategies for instruction and examination

A number of methods for instruction and examination are used in the civil engineering curriculum. The choice of method is normally deliberate, and compromises are made when conventional teaching methods are cheaper. Everyone concerned regret being forced to make such compromises.

Nevertheless, with few exceptions, the HEIs lack pronounced strategies for instruction and examination related to program and course goals, so that it is clear what has been done, when, why and to what extent. The exceptions to this are, above all, the programs that work according to CDIO principles. Decisions concerning instruction and examination are, in practice, decentralized to individual faculty members. This does not mean that there are no ideas about co-ordinating forms for instruction and examination, but that these are limited to individual courses or semesters, and they are generally not documented. Some faculty members the panel talked to expressed fear at the thought of being more controlled, but as long as forms for instruction and examination are the choice of individual faculty members, the system is

vulnerable. It only takes the loss of a few motivated instructors, for the quality of education to drop.

Without strategies, the HEIs deprive themselves of the advantages of offering programs – i.e. that not all types of instruction and examination need to be included in all courses. Instead, they can be allocated to different courses in the program. The necessity of viewing the civil engineering programs as integrated entities has been central to this evaluation.

A strategy for examination also makes it easier to ensure that the student workload is even and within reason. The students the panel talked to pointed out a number of cases in which the workload varied between courses awarded the same number of credits. This is understandably stressful and a source of irritation. Naturally, internal allocation of resources must be designed in tune with the strategy.

Throughput

In connection with this evaluation, figures on the throughput of civil engineering students were gathered by Chalmers University of Technology, the Royal Institute of Technology and from the universities in Linköping, Luleå, Lund, Umeå and Uppsala.[7] These figures provide information on how many students enrolled in the different programs from 1997 up to and including 2001, and how many students, three years after enrollment, have earned all the credits. There are also figures on how many students graduated of those admitted in 1997 after 10, 12 and 14 semesters. (For reporting purposes, these time points were chosen rather than the actual 9, 11 and 13 semesters, respectively.) Correspondingly, there are figures on how many students graduated after 10 and 12 semesters of those who enrolled in 1998, and after 10 semesters of those who enrolled in 1999.

What is most striking about these figures is that only a small percentage of the students, approximately 20 percent, had completed their studies within the timeframe for the programs, which is 4.5 years. After two more semesters, this figure increases to slightly more than 40 percent, and even after another two semesters, less than 60 percent have earned their degrees. There are no systematic differences between the HEIs, between program types, between male[8] and female students or over time. The throughput is the same even at HEIs with a high enrollment.

The figures are based on the students who begin the studies. The dropout rate for the first year, because a student has chosen the wrong program (and perhaps did not know what a civil engineering curriculum entails) or has not passed the courses of the first two semesters, is, according to the HEIs, so high that it explains a substantial part of the low throughput. This in itself is a major fault in the education and admissions systems, including the upper secondary school. The HEIs do a lot to aid the students, e.g. by means of introductory courses, extra help in mathematics and with mentors. Unfortunately, with the need to recruit students it is tempting not to make it clear just how demanding these studies are.

There is also a large group of students who were almost finished, but did not complete their studies. When the labor market is good, students are tempted to seek employment despite that they have not graduated. When the labor market

7. The civil engineering programs at the Blekinge Institute of Technology, Karlstad University, Mid Sweden University and Mälardalen University are too new to have data on throughput.

8. However, data from SCB (*Universities and Institutes of Higher Learning. Throughput and Outcomes in HEI graduate courses up to and including 2003/04,* Swedish only. Statistic communication UF 20 SM 0502) shows that the percentage of women graduates is significantly higher than the percentage of men over time. The percentage of students who earn a MSc degree in engineering eleven years after beginning studies is generally higher for women than for men.

is poor, students stay in school, for example, to take extra courses. In addition, many students feel that it is a better strategy to postpone graduation until they apply for their first job, so that their degree is not considered outdated. A third explanation for the low rate of throughput is that many students take a break after a few years, for example to travel. When the panel talked to students, it became clear that they do not think it is negative to postpone graduation. The students see this opportunity as an advantage rather than a problem.

When the panel asked the concerned groups at the HEIs about the efficiency of studies, the response was generally that results are good. However, results here mean student rate of achievement (fulltime achievement in relation to the number of fulltime students), or fulfilling the requirements according to the government appropriation directions. These are important parameters for the HEI since they determine the allocation of financial resources, but they are not a good measure of quality. Everyone is also reasonably satisfied with the total rate of throughput; most students who make it through the first year earn a degree sooner or later.

An aggravating factor in addressing the low rate of throughput is that there are no sufficiently good or uniform ways to measure throughput. Neither are there any local goals for the number of graduates. A lot of effort is spent on recruiting students, but less is spent on seeing to it that they graduate. Therefore, the panel recommends that all the HEIs with civil engineering programs agree on how to measure throughput and that they devise a system for gathering and monitoring throughput data. The panel also recommends that each HEI sets goals for throughput, with plans for action.

The time it takes to graduate is an important competitive factor on the labor market, a fact which the students do not seem to believe or understand. Trade and industry must clearly signal to the HEIs how important this is. Actually receiving a degree is important, not just a certain number of credits. Internationally, only degrees count. Consequently, it is not only an important competitive factor for the individual engineer, but also affects Swedish companies with international operations. For their own sake, students should earn a degree, in civil engineering or some other field.

The panel sees primarily two underlying reasons for the low rate of throughput. One of the them is the increasingly more varying, and in some students poor proficiency from the upper secondary school, concurrent with a dramatic expansion of the civil engineering programs, which increases the throughput time if the level of quality is to be retained. These conditions have changed at the same time that resources per student have decreased. The second reason is that the current system of allocating financial resources does not contain incentives for graduating, for the students or the HEIs. On the contrary; the student who remains in school and continues to study will have more credits, which raises the level of the school's achievement. Within the system of higher education, there is therefore no incentive to cut the long time it takes

to produce civil engineers, and there is no clear incentive for the students to graduate.

From an economic perspective, it is worrying that the efficiency of education is so poor. The underlying reasons for this, in the opinion of the panel, are essentially beyond the control or responsibility of the HEIs. Nevertheless, the panel feels that the quality of education is not good in terms of throughput.

The panel has the following suggestions for improving throughput:

- Introduce economic incentives for earning a degree, both for the HEIs and for the students.
- Give the relevant subjects in the upper secondary schools greater weight by giving them more credit when a student applies to a civil engineering program, to prioritize those who study these subjects and to mark that these are vital prerequisites for civil engineering studies.
- Increase funding per student so that the HEIs can afford to take additional action.
- Trade and industry should uphold substantial differences in pay between graduated employees and those who have not graduated, and otherwise act to promote graduation.

Student Work

Students are the most important actors in education. Evidently, the quality of graduating civil engineers, above all, depends on the students: their previous knowledge, effort, interest and commitment. The students often play an invaluable role in developing the curriculum; they actively participate in various drafting and decision-making bodies, the course evaluations that work best are conducted by students, older students are mentors, and students work actively in recruiting other students. There is often a strong sense of affiliation and pride in the education. As a result, the HEIs express pride in their students in the self-evaluations.

This is, however, not the whole truth. The panel discerns another, parallel picture: the number of students who apply to a civil engineering program has decreased and poorly motivated students are admitted. Previous knowledge from upper secondary school, particularly in mathematics, varies more now than just a few years ago, and some students are poorly prepared for higher education. The high dropout rate at the beginning of the study indicates that students do not know enough about the education to which they have enrolled. And the time students spend studying, in some places, is significantly less than is reasonable to satisfy education requirements.

The panel feels that it is important that the HEIs make clear how demanding an education in civil engineering is. Timetables and design of courses should be based on the effort required from students, in order to make it clear how much work is needed. This assumes that there are sufficiently good methods for quantifying student work load. Therefore, the panel recommends that the HEIs develop such methods and that students are taught to measure their work. Seeing time as a parameter is an important part of the study method students must learn to use. Some schools introduce study methods, for example, through lectures given by student guidance officers at the start of the first semester. The panel believes that more can be done to teach students how to prioritize and sort all the material they have to learn, and to time their work. This is also training for their future careers.

Previous knowledge and entrance qualifications

It is generally claimed that students enrolled in the civil engineering programs today clearly differ from previous student generations. Students today are a more heterogeneous group; while some have good previous knowledge, some have major knowledge gaps. This not only applies to mathematics, but also to technology, science and languages.

To be accepted to a civil engineering program the applicant must have passing grades from upper secondary school in mathematics E, physics B and

chemistry[9] A. The HEI can lower requirements, but not raise them. Because of difficulties in recruiting students, most of the HEIs have lowered the mathematics requirement to the D course level. The same applies to physics for which only the A course level is required. However, these are instances of lowering requirements. In the case of chemistry, the standard requirement is for the A level. For future chemical engineers, therefore, only the first upper secondary course is required. An education provider cannot raise the requirement to the B course without an exemption from the Swedish National Agency for Higher Education. The panel finds it unreasonable that an HEI cannot make decisions on relevant entrance requirements independently.

The panel can understand that the HEIs have lowered the entrance requirement in mathematics, but maintains that there are strong reasons to require mathematics E. The mathematics D course is usually completed in the second year at the upper secondary school. This means that students, who do not elect the E course, do not study any mathematics in their last year, which is a major disadvantage for a subject that requires practicing, like mathematics. In addition, when the entrance requirements to higher education are lowered, there is greater risk that students who are able to manage more difficult courses, do not choose them for tactical reasons.

It is the opinion of the panel that students who focus on these subjects should be encouraged. One way of doing so is to give these subjects greater weight in applications to civil engineering programs. Today's grading system leads to tactical choices which do not benefit anyone. It is unfair to the student and most likely increases the dropout rate during the first year. Also, compensating for gaps in previous knowledge, requires extra work and resources on the part of the HEIs.

9. Upper secondary school subjects are taught from levels A to E (mathematics), A to B (physics) and A to B (chemistry).

Faculty Work

The panel would like to draw attention to the situation of the faculty, particularly senior lecturers and promoted[10]professors. Faculty members work more than normal hours and must use part of their free time for teaching. Most often there is no time left for skill enhancement, such as developing teaching skills, or for keeping up with developments in relevant areas. Time that should be spent on research is consumed by teaching, since, as one instructor put it, "in teaching there is a deadline every day." The faculty situation has changed in that heterogeneous groups of students demand more from their instructors at a time when the work load should be reduced to avoid burnout. With such varying levels of previous knowledge, the faculty-to-student ratio, as well as remedial tuition, needs to be increased. Instead, cuts in funding have forced instruction in larger groups, less course development, fewer scheduled classroom hours and fewer lab exercises. In addition, remedial tuition is at the cost of other elements of education.

Nevertheless, in the talks the panel has had with faculty members, it is striking how many of them have turned disadvantage into potential change. This is a good mark of faculty creativity. Co-operation between faculty members, new teaching and examination methods, innovative ways of thinking on the whole – the civil engineering curriculum would not function without the commitment and professional pride of the faculty.

The need to compete for research funding has become great, and faculty members who are committed to teaching do not have enough time to seek financing for their research. This is particularly serious, since the faculty, now generally highly qualified, risk losing their research grants and consequently not be able to maintain their level of qualification. A holistic view of teaching and research is lacking and the situation is very alarming. The panel's distinct impression is that the system is overstrained and that the quality of civil engineers is at risk if no action is taken.

10. Senior lectures who are promoted to professorships do not automatically have their teaching load reduced.

Adapting to the Bologna Process

Coordinating European higher education, in the Bologna process, has brought to the fore the length of the Swedish civil engineering education. According to the present Degree Ordinance, it comprises a total of 180 credits, or 4.5 years. The concerned HEIs have strongly expressed a desire to extend it to five years, because it is a disadvantage internationally to have programs that are shorter than in other European countries. This applies to those who want to work in trade and industry as well as to those who want to continue their research abroad. The programs are to retain their character of a vocational education that also prepares students for postgraduate studies. The panel strongly backs this wish.

The panel suggests that an extension from 180 to 200 credits is used to include elements of sustainable applications of engineering; to increase training in personal and professional skills; to introduce mandatory work practice relevant to each curriculum and awarded with credits; and to enhance elements of entrepreneurship.

According to the terminology proposed by the Swedish government [11] a Master of Science in Engineering (civilingenjörsutbildning) would be a postgraduate degree and a Bachelor of Science in Engineering (högskoleingenjörsutbildning) a graduate degree. This is congruent with the way education is divided into cycles in the Bologna process. A basic assumption is that the first cycle is the basis for the second, but it is difficult to apply this idea to vocationally-oriented programs which can differ in both level and orientation. A program leading to a Bachelor of Science in Engineering is not a short version of a civil engineering program, since the programs differ in character. Engineering education has been a key problem in the Bologna process: how to include the two types of engineer in one system without destroying their distinctive characters. This is discussed in European countries with the corresponding two types of education. CESAER[12] and SEFI[13] communicate in a policy document that it is important that the system with a shorter, more practical, and a longer, more theoretical, education is not sacrificed in the name of the Bologna process.[14] At the same time, it must be possible to transfer between the two.

Considering that programs resulting in a Bachelor of Science in Engineering and a civil engineering degree, respectively, run in parallel, the panel suggests that the latter should be five years long but with an option to earn an

11. Swedish government proposition 2005/05:162, *Ny värld – ny högskola (New World – New Institutions of Higher Education, Swedish only).*
12. Conference of European Schools for Advanced Engineering Curriculum and Research.
13. Société Européenne pour la Formation des Ingénieurs.
14. Communication of CESAER and SEFI on the Bologna Declaration. Based on the joint seminar organized at Helsinki University of Technology, February 2003.

intermediate degree after three years. The civil engineering degree, after 200 credits, must be assigned postgraduate status, equivalent to a master's degree, to avoid the problems Swedish students confront abroad; despite its length, the current civil engineering education is compared with shorter programs, since it only leads to a first degree.

Another reason to retain the civil engineering program as a five-year, uninterupted program is that it would be difficult to motivate students to work hard the first three years, if it does not pay off. Since all students in Europe can compete for placement the two last years, there is a risk that students will choose to study first at HEIs with lower standards in order to get higher grades.

Obtaining a realistic volume of civil engineering education

Civil engineering programs are offered at eleven higher education institutions (Blekinge Institute of Technology, Chalmers University of Technology, Karlstad University, the Royal Institute of Technology, Linköping University, Luleå University of Technology, Lund University, Mid Sweden University, Mälardalen University, Umeå University and Uppsala University) of which four (Blekinge Institute of Technology, Karlstad University, Mid Sweden University and Mälardalen University) have offered the programs only a few years, at the longest since 2001.

In the past ten-year period, the number of civil engineers who graduate has increased by more than 60 percent. However, the first years of the 21st century have been marked by decreased interest. Despite the increase in the number of HEIs and the number of programs offered, the number of enrolling students has actually decreased. The HEIs have either started programs with fewer students or have cancelled programs in which the number of students was too small.

The number of applicants has decreased

The number of first choice applicants for the autumn semester 2001 was 10,534, which corresponded to an average of 1.55 applicant per new entrant. In the autumn of 2004, the number of applicants was only 9,117[15] but since substantially fewer students were actually enrolled, it was only marginally easier to be accepted (1.50 applicants per new entrant). The ratio has generally been smaller than 1.0, sometimes substantially smaller, at the four newest HEIs.

Number of beginners

	Fall 2001	Fall 2002	Fall 2003	Fall 2004	Difference 2001*–2004
CTH, KTH, LiU, LTU, LTH, UmU, UU	6,675	6,330	6,225	5,827	–848
BTH, KAU, MIUN, MdH	117	147	210	232	115
Total	6,792	6,477	6,435	6,059	–733

* Figures for autumn semester 2005 were not available when this report was printed.

Source: National Agency for Higher Education NU database.

Recruitment

To a certain extent, the reduction in enrollment during the period 2001–2004 can be explained by the general drop in the number of students entering higher education. However, interest in technical education has decreased more than

15. Swedish National Agency for Higher Education NU database.

can be explained by a smaller student population. There are several reasons for increasing the interest in civil engineering. One is that the quality of education is strongly linked to a sufficient number of well motivated students enrolling, and another is the labor market's need for civil engineers. The HEIs therefore invest considerable time and energy in recruiting young people to civil engineering programs, and the evaluation panel has seen a large number of good examples of recruitment projects. This also applies to co-operation with upper secondary schools in preparing students for higher education, for example, the project Matematik H (Mathematics H) at Linköping University which aims to improve the mathematics skills of upper secondary students.

Of all the recruitment efforts, there are some targeted to students who are under-represented in civil engineering, such as women, and students from homes without a study tradition. The panel believes that significantly more efforts targeted at these categories would benefit recruitment.

The HEIs have also created new program combinations, which students find attractive. A few examples are the Royal Institute of Technology's program for civil engineers and teachers, or the opportunity to augment a degree in civil engineering with economics, such as in Lund and Uppsala.

It would not be possible for higher education to enroll enough students with natural science qualifications in e.g. civil engineering programs if it were not for the opportunity to improve eligibility through a foundation year or adult secondary education. This is an excellent opportunity for students who regret their choice of upper secondary school program. The availability of qualified students and reforms to enable recruitment of new categories of students are central future issues for the HEIs that offer these programs. This also explains why major resources are taken from core operations and invested in marketing and other forms of recruitment, as well as in foundation year education.

The volume of civil engineering education

How many civil engineers should be trained? To answer this question it is natural to consider the future needs of the labor market. However, the need for people with a certain degree can change, even during the relatively short time it takes to train them, which makes it difficult to predict the need. Employment trends have been negative for civil engineers in recent years (between the years 2001 and 2003 the share of newly graduated engineers who were established on the labor market decreased by 12 percent) and few people predicted this change only five - six years ago.[16]

16. Establishment is however still high: only medical service professions, social workers and teachers have a higher level of establishment on the labor market than civil engineers (Swedish National Agency for Higher Education annual report 2005:26R).

Share established in 2001 of graduates from 1999/00	92 %
Share established in 2002 of graduates from 2000/01	87 %
Share established in 2003 of graduates from 2001/02	80 %

Source: Established on labor market. Graduates from 1999/00 and 2000/01, respectively. Established on labor market – graduated 2001/02, Swedish National Agency for Higher Education reports, numbers 2004:24 and 2005:42.

The conclusion is that the need for civil engineers is difficult to predict. Since a business cycle is approximately as long as an education cycle, accuracy in prediction is small, particularly for narrow, specialized programs. This makes it important that education is not so specialized that shifting needs between different lines of business make some types of civil engineer redundant.

Competition between HEIs?

To attain reasonable group dynamics and to learn teamwork skills in projects, classes should not be too small. Classes with approx. 30 students should be the minimum. The panel sees a risk in the fact that some of the civil engineering programs are so small, that they constitute meager learning environments, where joint studies with other student categories make it difficult to ensure educational quality. At some HEIs the civil engineering curriculum does not generate enough income and must be subsidized by other programs or by research funds. When the demand for an civil engineering education is low, it may be easy to conclude that it should be offered at fewer HEIs.

With the current system of allocating funding, Swedish HEIs tend to invest too broadly, in order to attract students and produce credits. This is natural since the current system encourages the production of credits. The hope that a greater interest in engineering, together with a new baby boom, will increase enrollment, entices more HEIs to offer civil engineering programs. The panel finds this unfortunate. Considering how small and vulnerable especially the new civil engineering programs are, the panel feels there is no room for additional programs of civil engineering.

Labor market needs versus student wishes

The type of civil engineering programs offered is goverened, above all, by student preference. This has created the paradox that there is a surplus as well as a shortage of civil engineers. Programs targeted to cover major needs in, for example, the chemical and forestry industries have been discontinued because they attract too few students. The skills to which students aspire are not always sought by the labor market. It is the opinion of the panel that there are no mechanisms that ensure a realistic volume of the programs. Too much, the education system is governed by interest; instead, labor market needs should be given priority, even if they vary and are very difficult to predict. In addition, industry needs to improve its forecasts of long-term needs for graduated civil engineers.

In conclusion, the panel suggests that an investigation is conducted into how realistic estimates of both student interests and labor market needs can be used as a base for planning. The panel recommends fewer programs with a solid and broad first few years, with the opportunity for many forms of specialization towards the end of the program. This would make the system more flexible, adaptable and accurate, which is a vital quality factor in the educational system.

Specialization and Ranking

This evaluation covers 97 programs, which is already a large number, but in addition, the programs contain a large number of specializations and other forms of electives. One reason that there are so many options is that the HEIs hope it will be easier to recruit students if something new and popular is offered. Typical areas that are currently considered to be popular are design, environmental studies, media studies, games and nanoscience. Another reason is that the system for allocating funds causes the HEIs to invest too broadly in order to attract students who produce results, which makes economic sense for the HEIs. The panel can understand the need to recruit students but feels that the current range of programs has run too wild and is difficult for an outsider to comprehend. Future employers, who, above all, want civil engineers with good basic knowledge, do not benefit from extreme specialization. The large number of narrow programs that exist today, i.e. programs that prepare students for a limited labor market, run the risk of not meeting future demands for civil engineers. The large number of programs and great flexibility also entails complications for the HEIs; students find it difficult to make choices, costs increase because similar courses are duplicated, etcetera.

There are several ways to deal with this. One way, which was also proposed in the section on obtaining a realistic volume of civil engineering education, is to have fewer programs with a broad solid base and several different specializations. This would give students freedom of choice in that they would not be forced to decide what kind of civil engineer they want to be from the beginning. These programs could be supplemented with a small proportion of programs or electives that are created on the basis of special labor market needs, and not intended to be permanent. The panel feels that it is important that the HEIs strategically review their programs and take a stand on curriculum structure. In this context, the panel would like to see specialization in areas where each HEI has particular strengths, linked to research.

If as many as eleven HEIs are going to offer civil engineering education, the panel feels that each HEI should concentrate on areas in which the school is strong. Ranking education, which may be considered to especially favor the large HEIs, can help the smaller HEIs by forcing them to focus on their strengths, and thereby improve quality. Ranking must be conducted on the program level to be meaningful. Nevertheless, in the long run, economic resources must be allocated on the basis of such principles and have such incentives built into the system that quality in education is promoted. The HEIs, for good reasons, manage their education according to existing conditions and demands.

The current system of allocating funds does not promote specialization and, in the opinion of the panel, should be reformed to include incentives for doing

so. Many countries have official or unofficial ranking of HEIs and programs. The panel has not taken a position on whether this is a suitable model for the Swedish civil engineering education. Instead, the panel suggests that an investigation is conducted into whether, and how, a ranking system could be used to increase quality and to provide incentives for strategic choices.

Internationalization

The current Degree Ordinance states that to obtain a degree in civil engineering the student shall ”take independent responsibility for development or utilization of new technology at an internationally competitive level”. It is understood that the education is to prepare the student for work abroad or in international business. While the field of technology, as such, is international, work abroad requires language and culture skills. It is important that these are part of the curriculum.

Student exchange

The aspect of internationalization that attracts the most attention at the HEIs is student exchange, and the panel finds that these efforts are generally good. To study abroad for a period of time is perceived as important by the HEIs, a view supported by the panel. Conditions for students from the civil engineering programs to study abroad, in the form of agreements with foreign HEIs, are good everywhere. Unfortunately, foreign exchange programs with the USA are difficult to accomplish for financial and other reasons. The HEIs also have staff responsible for internationalization, and internationalization offices that provide information on opportunities for study abroad. Some HEIs actively disseminate information, and some grants are available. Despite this, only few students travel abroad and the percentage has decreased rather than increased. At the HEIs or programs that have succeeded best, one fourth of the students take advantage of exchange programs. It is more difficult to persuade students to go to non-English speaking countries. However, it does not seem to be an impossible task, since the HEIs that work actively are more successful. The number of students who go abroad can be compared with the number who come here. Even though Sweden is a small country that can benefit considerably from increased openness, the number of students who come here is substantially greater than the number who go abroad. Probably, the fact that studies here are tuition-free is a contributing factor.

The panel has discussed this situation with the HEIs. The impression the panel has is that students are often so satisfied with the education they get at home, that foreign studies are considered to be an inferior alternative. Several students have indicated that foreign studies prolong the studies, which indicates problems in transferring credits from studies abroad. The panel finds that the view of foreign studies is too narrow. It is not reasonable to require that courses abroad completely correspond to courses here. Instead it is important to see the enormous benefits of foreign studies: individual growth and maturity, a cultural perspective, including on domestic culture, and not least, language practice. The panel would like to see this view reflected in all

information provided to students. The HEIs should also be generous with the right to transfer credits earned abroad.

The panel believes that the suggested expansion of the civil engineering education from 180 to 200 credits will stimulate international exchange since the Swedish education will then be more compatible with master's programs in other countries, once the Bologna process has been implemented.

Role of faculty

An international perspective is mainly provided by visiting lecturers and guest students. Consequently, there is a need to offer courses in English, especially later in the programs. The HEIs are willing to offer such courses, even if the majority of students are Swedish. In talks with the HEIs, the panel has discussed how this affects the quality of education.

Even if the response to the panel has varied, the students, to a greater extent than faculty members, have indicated that tuition in English is a problem. Class discussions are inhibited by the language and the ability to communicate specific terminology in Swedish is reduced. It is particularly difficult to communicate in Swedish with those who are not engineers, if only English terminology is taught. Another problem is the ability of faculty members to teach in English; it is easy to under-estimate difficulties in teaching in a foreign language. Good conversation skills and use of trade terminology can be deceptive. Teaching also requires being able to quickly give alternative examples of a phenomenon and to explain a theory. This ability is limited in a foreign language. It is also more difficult for faculty members to give feedback on reports and presentations if they are in English. The panel has noticed that some HEIs offer training in teaching in English, but that other HEIs are largely unaware of the problem.

In addition to teaching in English, faculty members contribute to internationalization by teaching from an international perspective. Faculty exchange receives less attention than student exchange, but there are exchange agreements. When the panel brought this up, the response was that faculty members spend time abroad in their role as researchers. However, giving a seminar, or teaching a graduate course, hardly constitutes teaching within a different educational system. Faculty members who do so will come home with new ideas about learning, as well as about what teaching and being taught in a foreign language entails, and will view the Swedish educational system from a new perspective. This type of exchange appears to be rare, but faculty members who have experienced it are very satisfied. The panel realizes that it is not always possible to spend an entire semester or a year abroad, teaching. It may be difficult to take time from ordinary activities at the HEI, including doing research and securing research grants. For this reason, the Mid Sweden University project in which students spend a few weeks at a foreign HEI, is interesting for faculty members as well.

Ranking education

As stated above, it is the opinion of the panel that Swedish civil engineers compare favorably with those who have an equivalent education from other countries. Nevertheless, it is a disadvantage to come from a small, non-English speaking country since Swedish HEIs are largely unknown outside Sweden. Not only the HEIs but also students and representatives of industry, have suggested that the HEIs be ranked in the same manner as abroad. Some Swedish HEIs have as a goal to hold a ranked position in Sweden or in Europe, but this is difficult without a method for measurement. In the USA, for example, a number of variables are employed to measure engineering programs by using weighted data to enable scoring according to relevance. With all due respect for difficulties in developing a fair method – for instance, poor faculty qualifications cannot be balanced against good student housing – ranking is possible to implement in Sweden also. The panel notes that Swedish universities and HEIs express a legitimate desire to show their quality and have it evaluated and recognized. It is a disadvantage for Swedish HEIs internationally not to be ranked. Based on this, the panel suggests investigating if a ranking system could be applied to civil engineering programs. Such an investigation should be conducted from an international perspective.

Women Civil Engineers

Since 1921, when technical education was made co-ed, the percentage of women enrolled in civil engineering education has increased, and a frequently expressed desire is that the percentage increases until the distribution between the sexes is more or less even. Civil engineers often end up in managerial positions which makes them an influential group, and such positions should not be held by one sex only. In addition, women have complementary perspectives and skills, which is important when coping with the difficult and demanding job of a civil engineer, particularly in the face of change and new challenges.

The seven HEIs that have offered civil engineering programs a longer period of time have provided data on the percentage of women students who started a program between the years 1996 and 2004. The four "new" HEIs have provided data for the years they have enrolled students in civil engineering programs. Blekinge Institute of Technology and Uppsala University distinctly differ from the other HEIs, which can be explained by the fact that they have, respectively, a smaller and larger percentage of programs that traditionally attract women.

Percentage of women students entering civil engineering programs 1996–2004*

	Blekinge	Chalmers	Karlstad	KTH**	Linköping	Luleå	Lund	Mittuniv.	Mälardalen	Umeå	Uppsala
1996		27		29	26	25	24			28	34
1997		26		31	26	31	27			26	35
1998		25		28	26	26	28			23	38
1999		29		31	26	25	28			24	40
2000		28		31	26	29	29			22	42
2001		24		28	29	29	28			23	37
2002	18	23		26	25	28	26			19	36
2003	15	23		25	23	26	28	26		20	33
2004	10	21	22	24	22	17	25	32	29	20	31
Average	**14**	**25**	**22**	**28**	**25**	**26**	**27**	**29**	**29**	**23**	**36**

* Data from self-evaluations, question 17 of the self-evaluation manual.
** Architecture program is included

Among the large number of efforts to recruit and retain students, there are a number that specifically target women: women student ambassadors, so called girl days or girl weekends, mentor programs, special web sites and networks for women. The table shows that despite these activities, the percentage of women enrolled has decreased in recent years.

One explanation for the reduction in the percentage of women enrolled in civil engineering programs is that women are more sensitive than men to a bleak labor market. This theory is supported by the fact that the reduction cor-

responds approximately in time with civil engineers finding it harder to obtain work. When times get worse, the category that traditionally would not choose an education reacts. The HEIs cannot be blamed for a failing labor market, but they can do more to increase the percentage of women students. Above all, they can increase the number of role models and reform the curriculum.

Women comprise a minority of the faculty at all eleven HEIs and the percentage is the lowest among professors. The percentage of women is approximately 15–25 percent. At talks, primarily with managers, the panel has asked about the nature of the support provided to women on the postgraduate level or to women who have recently obtained a PhD. It is evident that there are often visions in e.g. equal opportunity plans, but that these have not always led to concrete action. Generally, the departments receive support, rather than the women working there. The panel recommends that the support that is provided is made more concrete, more active and more targeted to the women themselves. For example, financial support could be linked to decisive career steps, such as a doctoral dissertation or becoming a senior lecturer.

In an investigation into engineering curriculums conducted in the late 1990s[17], differences between the needs and preferences of male and female students were discussed, as relates to teaching methods, educational content and educational goals. The conclusion was that textbooks and instruction in technology and natural science are more adapted to men's experiences. In addition, the culture at technical HEIs is often alien to women. The investigation notes that project work is assumed to suit women students. Projects tend to be more frequent in civil engineering curriculums, which would favor women students. Unfortunately, experience shows, according to the report, that work in groups often increases the workload for women since they assume responsibility for group dynamics. If this is true, it indicates that students are not given sufficient training in project work, project management and group dynamics or conflict resolution. The investigation also claims that freer ways of working are a problem because women have a greater need to have their performance confirmed, to be sure that they have really chosen the right education. Less traditional working methods may include work at night, which is a problem for the women who have children to care for.

The design of the civil engineering curriculum has naturally been a major issue in this evaluation. In their self-evaluations, the HEIs were given the opportunity to discuss the conclusions they arrived at in the self-evaluation process. However, none of the HEIs mentioned, in that context, the need to review education from a gender perspective. This does not mean that nothing is done. Efforts to view education from this perspective came up several times in talks the panel held with various groups, but the impression is that these efforts are tentative, and have little impact. It is obvious that the HEIs mostly see this problem as a matter of recruitment; when women make up half the

17. *Ny ingenjörsutbildning (New Education in Engineering, Swedish only)*. Ed. Ingemar Ingemarsson and Ingela Björck, 1999.

student body the problem will be solved. The panel recommends that education is reformed from a gender perspective so to make it more suitable for women. The issue must also, in the opinion of the panel, be seen in a larger context and the HEIs alone cannot influence and change the sex distribution of students and faculty, but rather efforts must be made on all levels.

Management of Education

The panel finds that the administration and management of education is of vital significance to the educational quality. This is true for short-term operative as well as long-term strategic management, organizational structure and its division of responsibility and authorization, and the way that quality is assured. The panel notes that policies, regulations and routines are not communicated throughout the organization so that they may be known on all levels. Consequently, it becomes difficult to implement the good ambitions that the HEI's often have. The panel notes, however, that organizational structure and management is sufficiently clear at most of the HEIs to enable integrated and good educational programs. The panel feels that it is vital to the quality of vocational education that the programs are truly coherent and integrated. There are some shortcomings at a number of HEIs that the panel would like to point out, below and in the section on individual HEIs. There is, for instance, generally no standardized design of syllibi and other documents describing goals, with provisions on what they should contain. The panel would like to see more distinct program goals and a clearer connection between the goals of a program and of individual courses, to make it possible to assure the quality of a coherent, integrated education. This would also help students see connections, and benefit their planning and choices. With few exceptions, the program organization is subordinate to the general HEI organization, since only the latter has economic policy instruments at its disposal. This means that responsibility and authorization are not always in line.

There is normally an organizational body that is responsible for quality of education, but on the whole, a systematic and holistic approach is lacking in quality work at the HEIs. Quality assurance is almost solely done on the course level in the form of course evaluations. The HEIs learn the views on education of future employers and alumni in informal ways. With a few exceptions, systematic, documented quality work, where all interested parties participate, is lacking. An important task for those responsible for education is to assure quality despite reduced resources. The panel sees the interaction between faculty and students as an important parameter of the quality of education. At none of the HEIs could the panel see that there were explicit goals in the form of teaching hours per credit, or relating teaching to funding.

The final, summing-up self-evaluation that has been a part of this evaluation is a structured method for evaluating education and suggesting improvements. It also forms the basis for regular follow-ups, evaluations and continuous improvements of quality. These self-evaluations have, with a few exceptions, been very well conducted, and the panel hopes and believes that they will constitute valuable instruments for the future development of the programs. The program committees are recommended to develop a tool simi-

lar to these self-evaluations, adapted to each individual program, and then use the tool in quality assurance.

The panel has conducted this evaluation from the approach of the CDIO model for civil engineering curriculums, as described above. Naturally, HEIs can have a different view of what a civil engineering education should be like. *In the opinion of the panel, it is important that an HEI has a well thought out and documented philosophy for the school's civil engineering curriculum, and that the education is designed, governed, managed, followed up, evaluated and continuously developed in accordance with that philosophy.* This is ultimately the most important issue in managing education.

Reports from the HEIs

The most important conclusions of the panel concerning each individual HEI are reported below in an itemized list. A more complete text including discourse on each HEI and their educational programs is available in a full text version of the report (in Swedish only), that can be retrieved from the Swedish National Agency for Higher Education's website, **www.hsv.se**.

Blekinge Institute of Technology (BTH)

- The civil engineering program is new which makes it difficult to evaluate them at this time.
- BTH has focused on education in Information Technology (IT) and has been effected by the general difficulty to recruit students to IT. The civil engineering programs have few students enrolled and they study in multidisciplinary groups.
- The undergraduate board and program committee determine curriculum, but cannot make decisions on execution since they lack policy leverage in the form of financial resources. The lack of connection between responsibility and resources undermines control.
- Assuring the connection between education and research is largely informal and thereby vulnerable.
- Interested parties are well represented in the program committee, but representation from trade and industry should be enhanced. There are also many good, informal ways of disseminating information, and informal collaboration. Contacts with future employers were good when the programs started but have since decreased.
- The goals for the civil engineering programs need to be made more distinct.
- One of the programs, in mechanical engineering, has a very good introductory course.
- Infrastructure, equipment and access to computers are excellent. However, civil engineering education is divided between two campuses and should be concentrated to one of them.
- Administrative support appears to be sufficient for faculty and students.
- Courses in environmental studies and engineering history are mandatory but other forms of sustainable applications are scarce.
- The forms for teaching and examination vary and a strategy for them is lacking.
- Many faculty members have a background in industry. The faculty qualifications are stronger in engineering science than in basic science, and the

percentage of junior lecturers is high. The percentage of women faculty members is lower than at the other HEIs.
- The current quality system should be enhanced and a good project in quality assurance has been introduced.
- The internationalization efforts consist, above all, in that many exchange students study for a master's degree in Blekinge. Students studying Information Technology will have the opportunity to study a period of time at one of foremost universities in the field in the USA.
- BTH provides post secondary education, as an introductory year, which is a good way to attract students from upper secondary school. BTH also actively recruits students from families who lack study experience.
- Thus far, student rate of achievement has been poor.

Chalmers University of Technology

- The civil engineering programs have a large volume which makes it easier to give them a good design. The close links to a strong research environment makes it easy to link education to research.
- Chalmers is one of the three Swedish HEIs responsible for the development of CDIO. Evaluation and development of education is excellent in the programs that follow the CDIO method.
- Chalmers has a new organization with a good division of responsibility between those ordering and those supplying courses, as well as clear lines of direction and control. The various drafting and decision-making bodies have a good mix of different actors and interested parties.
- Chalmers has, to a great extent, adopted the Bologna model of education. In connection with this transition the quality assurance of the system is being reviewed.
- The goals for the civil engineering programs should be more distinct and should include skill achievement to a greater extent. Program goals should be connected to course goals more clearly.
- The study introduction is good but many programs lack an introduction to the profession.
- The programs have a reasonable balance between mathematics, natural science and engineering science. All of the civil engineering programs provide education in environmental studies and sustainable development, but other parts of sustainable applications of engineering are optional.
- Too many courses are run in parallel, which makes it difficult to maintain a normal study tempo. Parallel studies have decreased from three to two parallel courses, however, which is good.
- Access to study halls and computers is largely good. The new organization should make it easier for students to obtain service and assistance.
- Faculty qualifications are strong and there is good access to teaching skill enhancement.

- There is active development of forms for instruction and the forms for examination also vary. However, strategies for instruction and examination are lacking.
- Internationalization efforts are very good.
- Contacts with future employers are largely based on the individual and should be made systematic. Alumni contacts have been weak but are under development.
- Outcomes are sufficient in terms of student rate of achievement, but poor in terms of throughput.

Karlstad University

- The civil engineering programs are new which makes it difficult to evaluate them at this time.
- The areas chosen for civil engineering programs at the university (chemistry and information technology) have had a hard time attracting students and the programs cannot defray their expenses. The number of students enrolled is so small that existing ambitions are difficult to implement, and the students must study in multidisciplinary groups with prospective Bachelor of Science engineers and natural science students.
- The organization that was in effect at the time of the evaluation was indistinct, particularly in the division of responsibility, and the civil engineering programs appears to have had an obscure position. As of 2006, the university has a new organization and it is important that the division of responsibility is clearer from now on.
- Faculty members and students are represented in decision-making bodies but there is no external representative on the program committee, which is responsible for the education meeting its goals, and this is a shortcoming.
- Educational goals vary in clarity from one program to the other and need to be communicated better in the organization.
- Not all the programs have a qualified introduction to the engineering profession.
- The university has thematic studies on a semester basis and teams of instructors, which is a good way of working.
- Contacts with future employers were good when the programs started, but has since decreased. Contacts are re-established through partner companies.
- There is a relatively large element of sustainable applications of engineering. Gender and liberal arts perspectives are included, which is interesting.
- Administrative support for faculty members and students has been well developed and hopefully will remain so in the new organization.

- Forms for instruction and examination vary but a strategy for them is lacking.
- Mathematics is made concrete by being treated as part of engineering science courses, which is a good way of integrating mathematics.
- Faculty qualifications are not on the same level as at the larger and more established HEIs and it is important to enhance the qualifications. The agreement on qualification enhancement is followed to an unusual extent, which is good.
- Infrastructure is good. The university is also investing in a special building for engineering and natural science educations.
- Internationalization efforts need to be developed and encouraged.
- Informal contacts between faculty members and students are good and are the most important form for student influence.
- Thus far, student rate of achievement has been poor.

Royal Institute of Technology (KTH)

- The civil engineering programs have a large volume which makes it easier to give them a good design. The close links to a strong research environment makes it easy to link education to research.
- KTH is one of the three Swedish HEIs responsible for the development of CDIO. Evaluation and development of education is excellent in the programs that follow the CDIO method.
- Many of the other programs have also gone through major reforms and modernization.
- As of 2005, KTH has a new organization with a good structure for responsibility, authorization, and incentives. It is important to clarify the relationship of the faculty board to the schools that are responsible for the undergraduate courses, in terms of assuring the connection between education and research, as well as the responsibility for quality follow-up.
- The representation of different interested parties, such as students, faculty members and external representatives, in decision-making bodies is good in general, but varies from one program to the other.
- Contacts with possible employers are good at KTH, but primarily through research, and restricted to individual faculty members. These contacts should be utilized better to promote education. The dialog with the surrounding world should be enhanced and made systematic. An alumni network needs to be built up.
- Educational goals are good and clear.
- Students are given a very good introduction to the studies, but many programs lack an introduction to the profession.
- The balance between mathematics, natural science and engineering science is reasonable. Elements of sustainable applications of engineering are, however, limited and largely optional.

- Forms for instruction and examination vary but a strategy for them is lacking in most of the programs.
- The civil engineering programs are offered at several campuses with different specializations. Infrastructure and equipment are good on the whole, but the quality can vary from one program to the other. The administrative organization should have good potential to provide faculty members and students with administrative support.
- With the exception of professional experience, faculty qualifications are strong. KTH has a Future faculty that discusses strategies for faculty qualifications and investments in women instructors. The Learning lab, which offers courses in teaching skills, is a very good resource.
- Internationalization efforts are excellent.
- The evaluation of education has many good features, such as linking meetings on some of the programs, but overall quality assurance needs to be more systematic, above all on the program level.
- KTH has introduced a housing guarantee for its students.
- Outcomes are sufficient in terms of student rate of achievement, but poor in terms of throughput.

Linköping University/Institute of Technology (LiTH)

- The civil engineering programs have a large volume which makes it easier to give them a good design. The close links to a strong research environment makes it easy to link education to research.
- LiTH is one of the three Swedish HEIs responsible for the development of CDIO. Evaluation and development of education is excellent in the programs that follow the CDIO method.
- Management is good, with a clear division of responsibility and authority. Curriculum committees purchase courses for the programs and thereby efficiently govern the content of education.
- LiTH uses a quality tool called "balanced scorecards" for its strategic and operative management, which in the opinion of the panel is a good way to work systematically.
- The curriculum committees appoint strategically important teaching and time planning groups with good representation. Other interested parties are generally well represented on drafting and decision-making bodies. There are external representatives on faculty boards and curriculum committees.
- Contacts with future employers are good. Alumni activities are being organized.
- The goals of several programs need be clearer and a review is in progress.
- Several of the programs offer courses that introduce students to the profession, but the role of the engineer could be made more visible in some of the programs.

- The balance between mathematics, natural science and engineering science is reasonable. Sustainable applications of engineering are not systematically treated and need to be enhanced.
- There is a wide range of courses, which is appreciated but causes scheduling conflicts and makes it difficult for students to plan, as well as limit, their studies.
- The LIPS project model is used by some of the programs and is an interesting initiative.
- Most of the programs lack strategies for instruction and examination. However, conditions for introducing such strategies are good because of the quality system that is used.
- The civil engineering programs are offered at several campuses, which makes student-faculty contact more difficult in some cases. Administrative support is good. Infrastructure and equipment are good, except for access to independent study halls, which is limited.
- Faculty qualifications are strong and efforts to improve teaching skills are ambitious.
- Internationalization needs to be made more concrete. Assistance to faculty members who teach in English needs to be enhanced.
- Evaluation of education is done in a good manner.
- LiU has the ambition of operating from a gender perspective, but more concrete work is needed.
- The mathematics project, "Matte H", intended for the upper secondary school level, is interesting.
- Outcomes are sufficient in terms of student rate of achievement, but poor in terms of throughput.

Luleå University of Technology (LTU)

- The civil engineering programs have a large volume which makes it easier to give them a good design. The close links to a strong research environment makes it easy to link education to research.
- "Arenas" are a new, interesting approach and have entailed investments in teaching skill enhancement, but have not had the desired effect on recruitment of students.
- The organizational structure is basically good, but gives the impression of being unclear in the division of responsibility and decision-making between prefects (who hold a very strong position), education directors, program coordinators and faculty boards.
- Future employers are well represented by means of two external members on the board of the engineering faculty and by means of external members on the program and "arena" boards.
- Overall, LTU has very good contacts with future employers.
- Educational goals emphasize engineering fundamentals, which is good.

- The introduction to studies is good and most of the programs have an introduction to the profession as well.
- All of the civil engineering programs have joint instruction in mathematics and natural science. The programs have a reasonable balance between mathematics, natural science and engineering science. Sustainable applications of engineering are not systematically treated, however.
- Some programs offer and arrange (voluntary) work practice, which is good and is highly appreciated by students.
- Forms for instruction are actively being developed and forms for examination also vary. Strategies for instruction and examination are lacking, however.
- Infrastructure and access to computers are good. Civil engineering education is offered at several campuses which is a problem when a program is located in more than one place.
- Administrative support functions satisfactorily. A common administrative computer platform at the university is a good investment.
- The research qualifications of faculty members are good on the whole.
- Internationalization efforts are good.
- Quality assurance on the course level is good, but should be improved on the program level, and there are conditions for doing so in collaboration with trade and industry.
- Outcomes are sufficient in terms of student rate of achievement, but poor in terms of throughput.

Lund University/Faculty of Engineering (LTH)

- The civil engineering programs have a large volume which makes it easier to give them a good design. The close links to a strong research environment makes it easy to link education to research. Access to other faculties provides good opportunity for widening the scope of study.
- LTH has clear and well structured direction and control. The division of roles between purchasers (curriculum committees) and suppliers (departments) is clear. A matrix organization assures interdisciplinary co-ordination of education, made possible by the diversity of the university.
- Students, employees and external interested parties are represented on all the drafting and decision-making bodies.
- Contacts with future employers should be improved.
- Course and program goals are good, as is work with goals on various levels. Goals are communicated well in the organization.
- The introduction to studies is good and there is good potential to develop the introduction to the profession.
- LTH is the only HEI that offers an engineering mathematics program, and many of the other programs are successful in the way they include mathematics.

- The overall structure of education is good. In an interesting project, LTH investigates how sustainable applications of engineering can be introduced as an integral part of all courses.
- There are two elective completions for students who wish to add economics to their degree.
- Forms for instruction are very actively being developed and forms for examination also vary. Strategies for instruction and examination are lacking, however. Procedures for degree projects are good.
- Some of the buildings are in poor shape and in great need of repair. There is a good study center, however, with reading rooms, rooms for seminars, computers, guidance officers and other staff.
- There is administrative support both centrally and on the department level, which has not been optimal, but this support is being reorganized, to become less vulnerable.
- Faculty qualifications are strong. Access to teaching skill enhancement is very good with a good system of rewards, but there is no policy for skill enhancement of faculty members.
- Internationalization efforts are very good.
- CEQ is a good basis for course evaluation, but needs to be developed. Quality assurance is systematic and functions well on all levels of the organization.
- Outcomes are sufficient in terms of student rate of achievement, but poor in terms of throughput.

Mid Sweden University

- The civil engineering programs are new which makes it difficult to evaluate them at this time.
- Enrollment on the civil engineering programs at the University is low. The difference between civil engineering and master's programs is indistinct and the university therefore has difficulties in creating integrated civil engineering programs. The great extent of instruction in multidisciplinary groups calls for caution so that the engineering character is not weakened.
- In the university's organization model, it is unclear who has overall responsibility, the faculty board or the program committee. The program committee lacks economic policy leverage, which makes it weak in relation to the departments. If the faculty board had a more distinct responsibility for quality, the link between education and research would be strengthened. Dependency on external funding is great, which entails a risk for vulnerability.
- There seems to be good representation of interested parties in drafting and decision-making bodies. Students are represented in all bodies, and the program committee has two members from trade and industry. There

is also a forum for co-operation in which mentors from trade and industry meet those responsible for the programs.
- A mentor program, which has not yet reached full effect, offers all students a mentor from trade and industry.
- The university has come far in developing goals as well as matrices for skills. If developed further, they will be excellent and create good conditions for well integrated curriculums.
- The current programs have no introduction to the profession, but a coming program, in engineering physics, has interesting plans for an introductory course.
- The balance between mathematics, natural science and engineering science is reasonable. Sustainable applications of engineering, however, are not systematically treated.
- The university needs to invest more in developing the program in mechanical engineering and design.
- Forms for instruction and examination have, up to now, not varied much. One program uses a matrix to provide an overview and indicate relationships, which is a good method and could form a basis for a strategy for examination and instruction forms.
- Education is offered at four campuses, but all mandatory courses are taught at one campus. Infrastructure and equipment are good, but the central study guidance needs to be reviewed.
- Faculty qualifications are sufficient in the IT program, but need to be enhanced in mechanical engineering and design. There is solid and generous investment in women senior lecturers.
- An interesting option for experience abroad is a one- to two-week ”intensive program.”
- Quality assurance needs to be enhanced and systematized. A new form for quality assurance is planned for the spring 2006.
- The university offers post secondary education, as an introductory year, which is a good way to attract students from upper secondary school.
- Thus far, student rate of achievement has been poor.

Mälardalen University

- The civil engineering programs are new which makes it difficult to evaluate them at this time.
- The number of students is small and it has been difficult to recruit students. The robotics program is interesting, but attracts few students.
- The curriculum is organized so that students study together to begin with and only choose to become civil engineers or Bachelor of Science engineers after three years. To a great extent, students independently combine their courses which makes it difficult to ensure a coherent education.

- The university is environmentally certified and all curriculums are to provide a base in sustainable development.
- The organization functions well, but those responsible for a program should be given a stronger and more distinct role together with the program committees. The faculty board should have a more distinct responsibility for long-term planning. This would create better overall responsibility for quality assurance.
- Students appear to be well represented on the various drafting and decision-making bodies. The program committee unfortunately lacks representatives from external interested parties.
- Contacts with future employers are relatively good. The COOP operation on one of the programs (education in co-operation with industry) is an interesting initiative.
- Goals for personal and professional skills need to be more distinct.
- The percentage of mathematics, natural science, engineering science and other subjects vary with student choice. Sustainable applications of engineering are, however, relatively well represented.
- Forms for instruction and examination vary, but a strategy for them is lacking.
- The civil engineering education is offered at two campuses. Infrastructure and equipment are new, modern and appropriate. The administrative structure appears to be well adapted to the program curriculum. If the number of programs increases, however, the structure may need to be reviewed to improve efficiency.
- Faculty qualifications are not very strong in general, but the instructors have good experience from trade and industry. There is a laudable investment in women instructors.
- The university has a good policy document for internationalization efforts.
- The curriculum is developed largely through informal work and the university should develop a more systematic way of assuring quality.
- Thus far, student rate of achievement has been poor.

Umeå University

- Civil engineering education in Umeå is quite large, relatively speaking. Ties to research are strong, which is evident from the choice of program types. However, the curriculum has evolved from the natural science curriculums rather than from an engineering science traditions. The university plans to apply for membership in CDIO and will thereby come closer to the technical universities.
- The management model can be improved: the role of the program committee should be made more distinct and it should have the stronger position in relation to the departments of economic policy leverage. In ad-

dition, the role of the university governing board should be made more distinct in relation to the faculty board. For example, it should be clear how the responsibility for civil engineering education is divided between them.

- In all the drafting and in decision-making bodies there are one to three student representatives, which the panel feels is good representation. The program committee includes representatives for faculty members, students and trade and industry.
- The Närkontakt (Close Contact) project in co-operation with the Royal Swedish Academy of Engineering Sciences, with the purpose of increasing long-term collaboration with trade and industry, is interesting.
- Program goals are good, but course goals vary greatly in quality.
- The introduction to studies is good. Some of the programs also have good introductions to the profession, and the drop out rate has decreased since these introductions were introduced.
- The programs tend to contain more basic science than is common in a civil engineering curriculum, but the distribution between basic science, engineering science and other subjects is reasonable. Sustainable applications of engineering are not systematically included in the curriculum.
- Forms for instruction and examination need to be developed and a strategy for them needs to be formulated. Procedures for degree projects are good.
- Infrastructure and equipment are good. There is a well developed web-based information system.
- The scientific qualifications of faculty members are sufficient or good, but their skills in engineering fundamentals could be better. The agreement on qualification enhancement is followed to an unusual extent, which is good.
- Internationalization efforts should be more active.
- A method for evaluating entire programs, with assistance from all involved groups, should be developed.
- Outcomes are sufficient in terms of student rate of achievement, but poor in terms of throughput.

Uppsala University

- Civil engineering education in Uppsala is quite large. The close links to a strong research environment makes it easy to link education to research. Access to other faculties provides good opportunities for widening the scope of study. However, the curriculum has evolved from the natural science curriculums rather than from an engineering science tradition. Several of the civil engineering programs have a design that differs from traditional engineering curriculums.

- The organization seems to function well but is complex. With more distinct roles and if the school of engineering had responsibilities and authorizations at the university, it would be clearer and the civil engineering education would have a more distinct identity.
- The different interested parties seem to be well represented in the various drafting and decision-making bodies. Representatives from trade and industry are included on the education and program committees.
- Student contacts with future employers are weak, but the extent of contact with trade and industry is growing.
- Program goals are good and good work is being done to ensure the connection to course goals by the use of goal matrices.
- The introduction to studies is good, but introduction to the profession is almost entirely absent.
- There is a striking difference between the programs in the distribution between basic science, engineering science and other subjects. Some of the programs have such a large element of ”other subjects” that it is questionable whether they are civil engineering curriculums.
- Too many courses are studied in parallel during the same time period, which leads to a heavy workload for the students.
- Students can attend a 40-credit course with an enterprise orientation, or add 40 credits in business administration to earn a Bachelor's degree in addition to the civil engineering degree.
- The information technology program has an interesting elective project course in which students, for instance, build a robot. This program has attracted a lot of attention and a large number of applicants.
- Forms for instruction and examination need to be developed, and a strategy for them needs to be formulated. Procedures for degree projects are good.
- Infrastructure and equipment are good, as is administrative support.
- The scientific qualifications, particularly in natural science, of faculty is good, but faculty members have poor experience from trade and industry. Financial support for women instructors is available.
- Internationalization efforts are good.
- Forms for evaluating education have developed well with, for example, evaluations of entire semesters. It is important that the opinion of future employers is included in evaluation.
- Faculty members have strong gender awareness, which has led to innovative studies and discussions.
- Outcomes are sufficient in terms of student rate of achievement, but poor in terms of throughput.

Appendix 1: Description of the Work of the Evaluation Panel

The evaluation panel

Members of the panel are:

- Billy Fredriksson (panel chairman): Technical Director at Saab AB, formerly professor of Fracture Mechanics and Fatigue at Linköping University, civil engineer in mechanical engineering, visiting professor at MIT, member of and vice president of the Royal Swedish Academy of Engineering Sciences, member of the board and former chairman of the International Council for Aeronautical Sciences, member of the British Engineering and Physical Sciences Research Council´s Review Panel, chairman of the research and education committee at the former MMT section at KTH.
- Karl-Fredrik Berggren: professor of theoretical physics at Linköping Institute of Technology, former chairman of the education committee for engineering physics and electro engineering, guest professor at Lund University, former project manager for CDIO in Linköping and member of the CDIO executive committee.
- Cristina Glad: executive vice president of BioInvent International AB, PhD in biochemistry, civil engineer in chemical engineering, former chairman of Blekinge Institute of Technology, former member of the board of Lund University, member of the evaluation panel in the quality audit at Umeå University, member of the Royal Swedish Academy of Engineering Sciences.
- Erik Höglund: professor of machine design at Luleå University of Technology, civil engineer in mechanical engineering, former dean of the engineering faculty and pro-rector at Luleå University of Technology, member of the Royal Swedish Academy of Engineering Sciences, deputy chairman of the expert committee for research at the Knowledge foundation, chairman of Holding AB at Luleå University of Technology.
- Hanna Jonsson: media engineering student at the Linköping Institute of Technology, curriculum monitor and member of the board of the student union, former study monitor at the Department of Media Engineering, formerly a student in Austria and Canada.
- Kristina Lundqvist: PhD in computer engineering from Uppsala University, researcher and instructor at the Department of Aeronautics and Astronautics, MIT, leads operations at Embedded Systems Laboratory, has introduced Computer Science/Software Engineering as a new element of

the aeronautics and astronautics educational program and is responsible for instruction in this field.

- Maria Severin: student of architecture and the built environment at KTH, responsible for the educational program at the school of Architecture and the Built Environment as student representative, formerly a student in South Korea.
- Anne Marie Wilhelmsen: Professor Emeritus of Architecture/ Building Design and Construction at Chalmers University of Technology, architect, former dean, member of the Royal Swedish Academy of Engineering Sciences, member of the evaluation panel in the quality audit at KTH, director of a Mistra program on environmentally adapted building, responsible for evaluations at the Swedish Council for Building Research.

The assignment

The evaluation of Swedish education programs in civil engineering is part of the evaluations that the Swedish National Agency for Higher Education has conducted since 2001. The panel defines its assignment as follows:

– The assignment is to evaluate the quality of Sweden's educational programs in civil engineering. The evaluation has three purposes: to check that programs meet minimum requirements as defined by goals and regulations laid down in law and ordinance and in the opinion of the panel; to support the development of the educational programs; and to provide information to concerned parties.
– The panel is to evaluate the programs with respect to factors that are important to achieving high quality civil engineers, focus on qualities and potential of the educational programs and disseminate good examples.
– The HEIs put a lot of work into self-evaluations and in producing data and information. Therefore, the evaluation should be designed so that the HEIs get the greatest possible benefit from the result, for their internal operations and for development work.
– Quality refers to the educational process as well as the outcome, under given conditions. The evaluation examines the management of the educational programs as well as the implementation and outcome, both on the HEI level and on the program level.
– The evaluation is to be set up and conducted in a manner that facilitates future follow up and regularly occurring evaluations.
– The panel reports to the Swedish National Agency for Higher Education but the primary target groups are the government, the HEIs and the educational programs as well as prospective students. Other target groups are employers and interested organizations, upper secondary educators, journalists etcetera. The report is directed, first of all, to the primary target groups and is structured so that they gain the greatest possible benefit from it. Special excerpts from the report can be provided to the other

target groups. This should be done in dialog with the Swedish National Agency for Higher Education.

The work process

The evaluation is based on self-evaluations and site-visits to the HEIs. Each HEI (11) and each of the 97 civil engineering programs has conducted its own self-evaluation. In addition, each program has conducted a summing-up self-evaluation in which they have assessed their program on the basis of a number of criteria related to a model based on CDIO and ABET[18].

The primary purpose of the site-visits was to clarify remaining questions after the panel's review and analysis of the self-evaluations. At the site-visits, the panel met those responsible for operations (as a rule responsible for the programs) and student guidance officers, students, faculty, those with strategic responsibilities (generally faculty boards) and administrative officers at each HEI.

Issue of panel disqualification

All members of the evaluation panel have or have had connections to one or more of the evaluated HEIs. Therefore, the panel has been forced to take a position on the issue of disqualification. At a meeting with representatives from all of the concerned HEIs held in January 2005 the issue of disqualification was discussed. The HEIs expressed a strong desire that all panel members participate in all site-visits. The panel has respected this desire and decided that the entire panel participate in all site-visits. However, panel members who felt that they were too close to a particular HEI did not take an active part in the discussions at that HEI.

Chronological order of the evaluation

January 2004: A coordinating committee formed by the concerned HEIs initiates talks with the Swedish National Agency for Higher Education.

April 2004: The Agency holds a hearing with trade and industry, as well as student and other interested organizations.

August 2004: A panel chairman is recruited.

September 2004: The evaluation begins with a meeting with representatives from the concerned HEIs.

Sept – Oct 2004: Instructions for the self-evaluation are drawn up in consultation with the concerned HEIs.

Oct – Nov 2004: Other panel members are recruited.

18. ABET is the foremost accreditation body for engineering and technology education at institutions of higher education in the USA.

December 2004: The Agency meets the students who are responsible for student participation in the self-evaluations.

January 2005: The panel begins formulating the approach and frame of reference for the evaluation.

January 2005: The panel discusses the approach and frame of reference of the evaluation with a reference group consisting of representatives from all of the concerned HEIs, and a few other interested parties.

February 2005: The panel chairman and the Agency discuss the self-evaluation process with contacts at the HEIs.

April 2005: The HEIs turn in the self-evaluations.

May 2005: The evaluation model is tested in a pilot evaluation.

September 2005: The panel makes site-visits to five HEIs.

November 2005: The panel makes site-visits to six HEIs.

December 2005: The panel analyzes its findings.

January 2006: The panel reports its findings.

Appendix 2: Twelve Areas of Evaluation

This evaluation has been conducted on the *program level*. This means that no specific subjects or fields of study have been examined. The evaluation panel has agreed that the following parameters determine the quality of an educational program. Information on each parameter has been retrieved from the self-evaluations that the HEIs and the programs have conducted, and supplemented and revised when the panel visited each HEI (site-visit).

1. Direction and managment

Appropriate organization and decision-making systems and administrative support are prerequisites for good education quality and cost efficiency, both in the short-and long-term. This applies to both the HEI and program levels. Planning and management are means for developing the quality of education. The organization should be simple, clear and transparent as well as flexible and distinct in the division of responsibility. Information and communication that function well ensure that decisions are known and supported. The parties interested in the education, i.e. faculty members, students, and future employers, are represented on drafting and decision-making bodies.

2. Goals and goal documents

Clear and well-known goals are part of providing students with a suitable platform for their future working life, and consequently goal documents can be seen as a contract with the students. Educational goals show educational context, i.e. the framework for the knowledge of engineering, as well as the personal and professional skills the students are to acquire. The goals should describe the characteristics of a newly graduated civil engineer as identified by engineering organizations, representatives from trade and industry and other interested parties.

3. Integrated syllabi

An educational program is governed by a syllabus with courses that form an integrated education in which the content of each course is connected to the goals of the program. The courses are mutually supportive, i.e. there are clear links between the content and goals of different courses. Programs are set up to result in the intended skills. Program introduction aims to stimulate student interest in studies and to increase motivation for engineering work by highlighting central applications of engineering fundamentals. Mandatory parts are balanced against elective parts. The design of the curriculums is supported by different interested parties and there are mechanisms for assuring the connection between design and goals.

4. Content of education

The civil engineering education comprises knowledge specific to fields of engineering that provides students with the qualifications for working in that field. Mathematics and natural science subjects are included to the extent and in the manner that is suitable for each program, to enable students to understand the fundamentals and be able to apply them to the chosen area of technology. The program also contains subjects in addition to engineering and natural science subjects, to provide students with a broader perspective. Engineering applications taking into account the abilities and needs of human beings, social conditions, economy of resources, the environment and economy are trained throughout the studies. In addition, students' cognitive and personal development is promoted and the ability to work in teams and communicate is trained.

5. Deliberate choices of forms for instruction

The goals of the educational programs are achieved through deliberate choices of forms for instruction, from a didactic approach that integrates subject-oriented learning with the attainment of personal and professional skills and knowledge of system and product lifecycles. Active learning and problem-solving promote students' learning and self-reflection. Students become more motivated to achieve program goals, and practices for life-long learning are formed. Methods for active learning train critical thinking, support students in the process of finding connections between key concepts and help them apply this knowledge to new areas. Student participation in instruction is part of their training in communicating their knowledge.

Project courses, for instance "design-build-test" projects, are designed and strategically located in the curriculum, to give students early and positive experience of performing engineering tasks. With recurrent project courses and increasing complexity, students' understanding of product and system lifecycles is gradually increased.

6. Supportive learning environment

The physical learning environment comprises infrastructure in the form of lecture halls, seminar rooms and study halls, as well as laboratories and computers with relevant software. The learning environment is user-friendly, accessible and promotes social interaction and learning. A library that is accessible and equipped with appropriate literature is part of the learning environment. Geographical location at more than one campus does not impede accessibility.

7. Faculty qualifications and teaching skills

Faculty qualifications are central to the success of education. Both current research qualifications and professional engineering skills are necessary parts of faculty qualifications and must be in sufficient supply. There must be time reserved for skill enhancement, for instance by sandwiching instruction with

work in industry. Instructors have good teaching skills and opportunities to develop these skills. Guest research fellows and guest lecturers are involved in the teaching.

8. Examination and degree projects

Examination is used as a tool to measure how educational goals are met. The forms for examination are adapted to different forms for instruction and to course goals, and thereby aid in creating breadth in learning and to greater credibility and validity of data on examination outcome. Degree projects sum up student knowledge. The level is sufficiently high and the project shows critical thinking and a scientific approach. External degree projects in collaboration with industry occur or may even be frequent.

9. Internationalization

The syllabus ensures that all students obtain an international perspective through course literature, choice of examples and/or international experience of faculty members. The syllabus allows for spending part of the time studying abroad; the school works actively to see that many students take advantage of this opportunity and there are clear incentives for students to study abroad. The schools are prepared to receive students from other countries. There is knowledge of how well civil engineering education compares with equivalent education in other countries.

10. Evaluation of programs

The evaluation serves as a basis for continuous improvement of e.g. efficiency and goal attainment. This is a central task for those responsible on different levels. Information is obtained from instructors, students, other staff, alumni and future employers. The methods used to gather information are such that it can be utilized optimally.

11. Flexibility, adaptation, innovation

The HEI follows societal and other changes that affect its operations and is prepared to adapt the use of resources. Examples of this are varying levels of previous knowledge and preferences of students, greater competition for funding, changes on the labor market and in professional roles, and, not least, adapting to other European countries through the Bologna process. The HEI has strategies for reform, such as initiating or discontinuing educational programs. Adaptation to different factors in the surrounding world is weighed against the need for stability. An even distribution between the sexes, as well as social and ethnic diversity, are strived for.

12. Outcomes, qualitative and quantitative

The qualitative outcome of education is the difference in knowledge, ability, values and perspectives between when students enroll and when they gradu-

ate, i.e. ”the refinement” of students. The quantitative outcome of education is the production of credits, the rate of throughput and the number of graduates. Other types of outcome are the establishment on the labor market and the transition to postgraduate studies.