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The Field of Technology in Sweden: The Historical Take-off of the Engineering Professions

Abstract: Although the engineering profession has been called “the failed profession” owing to its lack of social closure, engineers have been successful in claiming their area of expertise and specialized knowledge as legitimate areas of research, knowledge, and intervention. In this article, the historical development of engineering professions in Sweden is used as a case of professional development. With the use of primary statistical sources and secondary historical sources, I endeavor to explain engineers’ professional development via coinciding factors such as the expansion and scientific content of lower and higher engineering education, the struggle for power in interest groups and unions, and engineers’ position in what seems to be an ever-increasingly diversified labor market. I argue that the professionalization process for Swedish engineers has fluctuated and that more than one professional take-off (two or even three) has occurred.

Keywords: technological field, engineers, professionalization process, take-off, social closure, diversified labor market

Research on the professionalization of engineers shows that despite a common founding in science and mathematics, the profession is heterogeneous, with little unity between different specializations; that is, engineering is not one profession but many (Larson, 2006). The profession is characterized by a diverse social division of labor where engineers work in different areas and apply their knowledge to diverse needs with a common cognitive base oriented toward practical use. Owing to a weak correspondence between engineering education and the unclear definitions of task assignments and to the unsuccessful monopolization of the task assignments (Nygaard, 2013), engineering labor organizations have generally been weakly organized. The profession has been rather uninterested in forcefully articulating its common professional interests. It has been named “the failed profession” (Brante, 1990, p. 88) and has historically had to overcome professional challenges, which persist today. From 1955 to 1965, the number of engineers in Sweden almost doubled from 22 000 to 43 000 engineers. Today, more than 300 000 engineers are in the labor market, dispersed in 339 different occupational status codes with at least three different levels of education; however, of these, only 51% have finished their studies and earned an engineering diploma (Statistics Sweden, 2013). In relation to social closure, engineering is certainly a failed profession (cf. Torstendahl, 1991).

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Received:
12 March 2013

Accepted:
25 November
2013

Nevertheless, engineers have successfully claimed their area of expertise and specialized knowledge as legitimate areas of research, knowledge, and intervention. Their professional project has resulted in their claiming the expanding technological field as the legitimate jurisdiction of engineering expertise, and, to a large extent, they have achieved autonomy and control of the content of their work. Within the system of technological professions (Abbott, 1988)—the technological occupations occupying the field of technology—engineering has achieved status as a winning profession based on engineers' mastery of complex knowledge, the development of formal education, and the issuing of state-sanctioned diplomas (even though the labor market accepts engineers without diplomas).

My primary aim is to describe the parallel quantitative and qualitative take-off(s) of engineers that have occurred historically and the partial failure of the professionalization of engineers in Sweden (see the article by Brante in this issue of *Professions & Professionalism*). I also endeavor to explain the professionalization of the technological field, leading up to the contemporary professional landscape for engineers (Brante, 2010b). With the use of primary statistical sources of labor market activity, the number of students enrolled in engineering, the number of diplomas issued, and the synthesis of secondary historical data, Sweden is presented as a case of professionalization processes. Sweden is chosen because of its distinguishing characteristics compared with many other well-studied national engineering professionalization histories, such as those of France, Germany, Great Britain, Norway, and the United States. From the start, engineering professionalization in France was dependent on state organization and demand, both for military and civil reasons (Weiss, 1982). In Britain, the quest for professionalization in engineering was characterized by traditional craftsmanship and apprenticeship rather than higher theoretical education. British engineers seem not to have had the social, political, or work-life ambitions to claim professional status in the 19th century and well into the 20th century (Buchanan, 1989; Torstendahl, 1982a, 1985). In Germany, academic studies with theoretical content constituted a part of the arguments for professionalization, but the engineers' relationships with practical knowledge and with bureaucracies put them in an awkward position; that is, they were stuck between a twofold ideal of autonomy within the industry and a position within the state bureaucracy where they did not fit in (Gispen, 1989). In the United States, the professional engineering organizations were dominated by engineering managers. Instead of fostering an autonomous position for engineers in the labor market, these organizations remained under the control of branches and big corporations (Layton, 1986). The engineering profession in Norway became influenced by the development in the United States after the Second World War and had its golden years from 1945 to 1965 (Nygaard, 2013). The Swedish case is presented in the following paragraphs.

Earlier research on the professionalization and historical expansion of Swedish engineers has examined the numbers of engineers in lower and higher education and of diplomas issued, as well as the dispersion of engineers in different occupations (Ahlström, 1982; Berner, 1981/2012; Torstendahl, 1975a). My contributions to this research tradition involve presenting some updated data and showing how the data relate to the contemporary technological field. In this article, I argue that more than one professional take-off (two or even three) has occurred for Swedish engineers, thus explaining the partial failure of the professionalization process.

Conceptual notes

Vincenti states that “engineering refers to the practice of organizing the design, construction and operation of any artifice which transforms the physical world around us to meet some recognized need” (1990, p. 6). The generalized cultural value and the social functions of engineers are to contribute to the transformation of the world in a way that helps humankind and, ultimately, to the growth of economies. The technicians, especially engineers, are crucial for the fulfillment of the high expectations that society places on these functions.

Professions are defined in relation to the knowledge they recognize based on scientific knowledge; in other words, they are mediators and appliers of the highest knowledge in a technological field (Brante, 2011; see also the article by Brante in this issue of *Professions & Professionalism*). The technological *field* is, as a concept, influenced by Bourdieu but not necessarily in a strict sense. The technological field should be understood as a social order of relations structured by “the distribution of species of power (capital) whose possession commands access to the specific profits that are at stake in the field” (Bourdieu & Wacquant, 1992, p. 97). The field involves the struggle between actors for symbolic or material assets—for instance, for recognition and higher positions and more power and capital within the field. The technological field includes not only struggles but also cooperation between professions—for instance, in the division of labor between different engineers (with different specialties and levels of education) and between engineers and other occupations such as technicians (see the article by Brante in this issue of *Professions & Professionalism*). Thus, the concept of field helps in understanding the factors that have affected the conditions for professional take-off of engineers and the possible consequences involved.

The engineering professions’ *qualitative* take-off relates to the professions’ increased social or economic status and importance in society based on cognitive development (i.e., the combination of practical and theoretical knowledge), new scientific paradigms, the institutionalization of engineering education, or the breakthrough of inventions (Brante, 2010a). The *quantitative* take-off signifies increases in numbers of engineers in relation to previous development and to other professions in the technological field. A quantitative take-off implies the previous introduction of practical innovations, theoretical breakthroughs, or social changes (e.g., the Industrial Revolution), creating increased demands for engineering competencies and engineers. The qualitative take-off may then lead to quantitative increases when a new paradigm or a new technology promotes industrial or public demands for new technological specialties—even if other engineering specialties become obsolete. To understand and explain the take-offs of engineering professions, the following historical factors must be considered:

The *first* factor is the historical relationship of engineers to science and technological breakthroughs after the first Industrial Revolution (1850–) and at the beginning of the second Industrial Revolution (1890–), which represent important starting points (Schön, 2012). The *second* factor is the formation of engineers’ interests in organizations such as unions and interest groups. The *third* factor is the stance of the state in relation to engineers and their functions. The state is especially important for legitimizing the demands of engineers to professionalize through the expansion of lower and higher engineering education, investments in research, and a strong demand for technological experts in the service of the state

(Freidson, 2001). The *fourth* factor involves the effects of the position of engineers in what seems to be an ever-increasingly diversified labor market, perhaps especially important at the time of the third Industrial Revolution at the end of the 1900s when new information technologies transform the world (Schön, 2012). In my opinion, the four factors are necessary but insufficient in explaining the professionalization of engineers. Other factors that help explain the professionalization of engineering (but are not covered in this brief article) include the change in specific work content and the institutional and organizational context in which various engineers perform their work.

Early history

The systematization of engineering knowledge, based on science and mathematics, became formalized into higher (military) education in the 15th century and influenced independent engineering innovators (Dahl, 1995). Military needs were the main driving force for technology development, creating a demand for specific technologies for large-scale projects. The first non-military engineers were typically self-employed consultants in mining and iron industries, but the growing influence of industrial capitalism later transformed the engineer into a laborer rather than an independent innovator. It became the employer's prerogative to decide how and to what purpose the engineer's tools and products should be used (Harms, Baetz, & Volti, 2004). The changing working conditions were accompanied by demands for diversified competencies, which led to disciplinary specializations and new organisations (i.e., mechanics' development of more sophisticated machinery in turn made manufacturing more effective). The two known energy systems—living energy (human and animal power) and mechanical power—were complemented in the mid-1800s by electric power; together with the science of thermodynamics, they comprised a paradigmatic shift.

Although the first technological experts in Sweden typically came from Continental Europe at the beginning of the 18th century, the number of technologists of Swedish origin was growing. Increased know-how and knowledge transfer led to an adaptation to local circumstances and improvements in already existing technologies. Domestic inventions and applications of scientific research became more and more important (Björck, 2009; Dahl, 1995; Lindqvist, 1989; Torstendahl, 1975b). The formation of the technological field was still to come.

The formation of the technological field: 1840–1915

By the end of the 18th century, a more coherent and systematized technological bulk of knowledge had developed. Jernkontoret (the employers' organization of the Swedish steel industry, est. 1747), agricultural societies, and the Technological Institute (est. 1827; transformed into The Royal Institute of Technology, KTH, in 1877) were the main institutions that advanced technological knowledge. Not until organized industrial capitalism was in place around 1890 could the experiences of engineers in mining and iron industries be used as stepping stones for the professionalization process (Björck, 2004; Torstendahl, 1985). In the 1890s, the use of applied technological science, rational planning of engineering skills, and spread of

new technologies (i.e., the steam engine, electricity) allowed industrialization to take a new direction (Schön, 2012). Engineers became indispensable to the new and prosperous companies that made their fortunes on specialized and export-oriented products. Companies such as ASEA, SKF, AGA, and Alfa Laval were created and managed by engineers (Torstendahl, 1991).

A whole range of newly established institutions, usually state organized, became crucial for the development of industrial and technological processes. These in turn were important for the legitimacy that engineers came to enjoy through increased product quality (Björck, 1992). The increasingly coherent technological knowledge laid the foundation for an extended power of engineers in labor markets and among the elites in society. Engineers, in competition with mainly lawyers and economists, often occupied important positions in society at the turn of the 20th century. Even though—or perhaps because—they were a small group of men with tightly knit networks, engineers were now leaders of big corporations, experts in state investigations, opinion-makers, public officials, and politicians (Torstendahl, 1975a). New technologies created a stronger demand for engineers to control and minimize risks in a more complicated technological world. Engineering organizations portrayed themselves as those best able to organize and rationalize society, and explicit demands were made on the content and quality of educational programs.

The expansion of lower and higher engineering education

Most of the technological education before the mid-19th century occurred outside of educational institutions, mainly in workshops in the industries through different systems of apprenticeship and self-tuition. The Swedish Handicraft Association organized a school that was open on Sundays and evenings for craftsman apprentices in 1845. Its goal was to ensure that its pupils gained approval to continue to higher studies.

In the 1850s, a number of mechanical institutes were established to provide technological competences on a lower level, mainly in classes offered on evenings and Sundays. Their aim was to provide a fundamental knowledge of natural science and a basic vocational training, but they were unsuccessful (Torstendahl, 1985). The fear of a shortage of engineers with adequate competences resulted in increased demands for alternative educational pathways and reformed programs in lower education. More pupils turned to the technological schools that were open on evenings and Sundays to receive their education. These schools had been established as a way in which to overcome the social and class barriers for entering higher education (Torstendahl, 1975b).

At the end of the 1860s, the first equivalent to upper secondary level education (gymnasium) in engineering was started at four schools that were financed and regulated by the state. They were scattered across the country and designed to give a general technological education and to motivate students to continue studying at higher, more specialized levels of study. However, in the 1870s, these “middle-level” schools were, for political reasons, mandated to train foremen exclusively (instead of engineers), thereby becoming a dead end for higher studies (Torstendahl, 1985). This was a successful exclusion of working-class families with reduced means to higher education—in effect, a social closure.

At the turn of the 20th century, the first private technological institutes were established. These institutes, particularly evening schools, attracted pupils with a variety of occupational aspirations. With the expansion of lower engineering education, and as the complexity of technological knowledge grew and the use of more advanced machinery in industries demanded special knowledge, the general engineering profession needed to be supplemented with specialized competencies through higher education.

Despite severe criticism against institutionalizing higher engineering education—based on an argument for free competition and rights to establish for private actors—mining education and the Technological Institute were established in the 1820s. Beginning in 1818, military engineers entered higher education at Marieberg, Stockholm. In 1834, the subjects of topography and road construction and water construction were first taught—hence, the title engineer (in Swedish, *civilingenjör*).

Higher engineering education was considered a practical field. Science could only be legitimized if it were of practical importance to the industry or the state. As higher education in engineering gained ground, the claims for scientific substantiation also became more frequent. Those who favored engineering as a way of creating new, better industrial products and economic growth viewed physics and chemistry as the core scientific disciplines. However, the resources needed to provide professors and lecturers with decent salaries and the number of hours needed to teach students theoretical and practical content was considered too limited to constitute a proper scientific education (Torstendahl, 1975b).

New local regulations at the Technological Institute in 1846 led to a changed hierarchical order between practice and science. The role of professors and, thereby, science expanded. The length of education increased from 2 to 3 years (Torstendahl, 1982a). Mathematics and foreign languages became entrance requirements. Science became the core cognitive base; mathematics, physics, chemistry, and mechanics were emphasized as a common scientific corpus for all engineers, irrespective of specialty. The endeavor of the engineering profession to become scientific was successful, and science soon helped engineering to expand into new jurisdictions. A cognitive closure based on multi-paradigmatic coherence, new innovations, and an expanding technological field helped the role of engineers become more apparent. They gained sufficient legitimacy and power to point out that they should be in charge of technology.

The Technological Institute became a technical university college (KTH) in 1877 with the establishment of five new colleges: machine construction, chemical technology, road and water construction, mining, and architecture. This institution quickly earned a reputation for providing high-quality education. Whereas many Swedish men in the past had traveled to France, Germany, Great Britain, or the United States to receive an engineering education, they now found a competitive education in their home country.

The investments in KTH supported thesis writing, and an official diploma in engineering was first issued in 1915 (without legal protection, Berner, 1996). The establishment of a formal diploma in engineering marks a crucial factor for the qualitative take-off for engineers as a profession. Another such mark was the acceptance of women into engineering education in 1901. (Women were, however, discouraged to apply; they were accepted on only a case-by-case basis.) Officially,

women were not allowed to study at the university level in technology on the same basis as men until 1921 (in other academic disciplines, women first gained acceptance in 1873) (Berner, 2000).

A state initiative, introduced in the first decade of the 1900s, aimed to develop science and technology of practical use in industries. It led to a forceful expansion of higher education. As part of its organization and design of higher education for engineers, the state regulated that universities educate engineers both for the purposes of the private labor market and the state, including the military. The private companies needed high technological competence, partly owing to huge orders from the state for technological infrastructure (energy, water and sewage, and communication) and to increased exports of Swedish products. The state also had an increased need for competent bureaucrats and officials to supervise or control the work of engineers in the private sector (Brante, 1990).

By the turn of the 20th century, about 2000 engineers had earned their higher diplomas. The number of technology institutions at the universities increased rapidly but not as fast as the number of student applicants. As shown in Figure 1 below, the number of engineering students increased steadily from 1834 to 1914. From about 1890—and especially from 1897—onward, the number increased more dramatically.

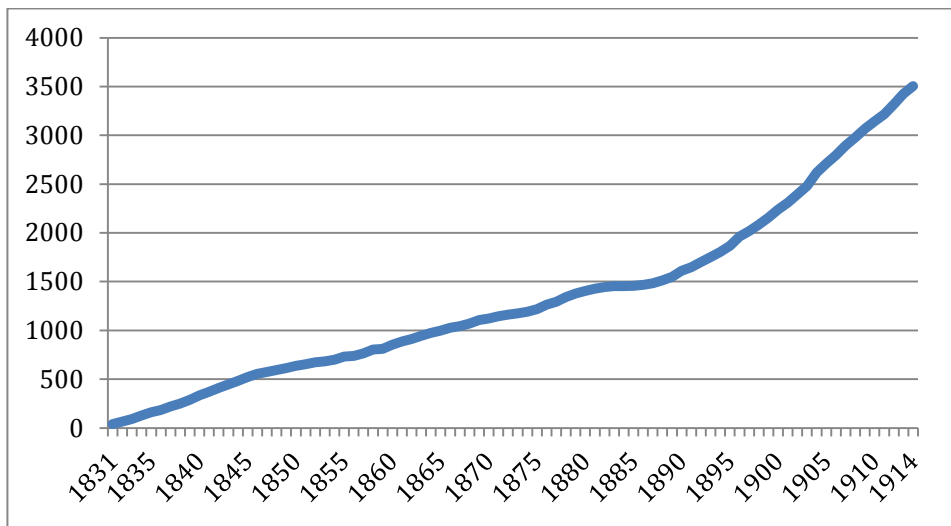


Figure 1. Enrolled engineering students at KTH and Chalmers 1831–1914. Adapted from Ahlström (1982).

The increases happened despite criticism from the university faculties who wanted only applicants with an upper secondary diploma to be accepted. However, the industries and the state, recognizing the need for more engineers (even those without a previously earned diploma), ignored the criticism. From 1884 through 1898, KTH accepted 100 new students annually, and an additional 25 new students from 1899 through 1902. In 1903, the number of new students nearly doubled (from 125 to 240 students), and the number of professors increased from 13 to 25.

At the beginning of the 1900s, Chalmers School of Technology in Gothenburg also increased the number of accepted students from 125 to 150 students a year. In light of that increase, it argued for a status upgrade to Chalmers University College of Technology. Because a number of committees—most of them dominated by

KTH representatives—concluded that only one university was needed in Sweden and opposed investments at Chalmers and other institutions, Chalmers had to wait until 1937 for their new status (Björck, 2004). This opposition to a status upgrade was a way to control the barriers for entrance by reducing the overall number of accepted students and increasing the demands on the right to examine enrolled students. This situation and a downturn in the economy during the First World War and the interwar period led to delayed decisions for further expansions.

In the meantime, possessing a diploma from upper secondary schools became mandatory for students to qualify for entrance to university engineering programs. This qualification was also a successful social closure measurement in that new technologists aspiring toward a higher diploma came from well-off families, thus creating a more homogenous student corpus and an elite profile at the KTH (Torstendahl, 1975b).

After the 1893 World's Fair in Chicago, both business and the educational institutions invested heavily in laboratories for upgraded practical activities. Engineers argued that they were the assigned actors of applied science, and the status of the occupation increased from workshop mechanic to an elite group of refined technical specialists (Björck, 2004).

Engineers' organized interests

Among civil servants, technologists were the first to create an association with union characteristics. The Mechanics (Maskinist) Association started in 1848 and soon became an association of interest. It was mainly occupied with issues of continuing education, endeavoring to uphold the level of education for newly recruited technicians and to strengthen the general interests of the occupation. At the turn of the 20th century, many new engineering associations started—some located in industrial plants and others organized in branches—that attracted mainly middle-level engineers. They were rather easy to organize, especially when their interests were threatened. Despite differing opinions regarding what type of functions the organizations should perform, they still had a common understanding of their identity as engineers (Torstendahl, 1982b).

The student organization (est. 1855) at the Technological Institute became the Swedish Technological Association (STF) in 1877; its primary aims were to increase the status of engineers and the demand for their services. By the turn of the 20th century, the STF had organized 1400 members. In 1865, another engineering organization, the Society of Engineers, initiated efforts to organize the interests of publicly employed engineers (Torstendahl, 1985). Both organizations wanted to inform not only their members but also the general public about their activities and aims. The founding of a number of engineering magazines and journals provided a way in which to define and expand their jurisdiction by emphasizing their power of expertise in separate fields (Björck, 2009). However, differences in interest and opinion existed between various organizations; in 1910, the STF was split into two different organizations, the STF and the Federation of Swedish Industries (today, a part of the Confederation of Swedish Enterprise), which was dominated by large industrial organizations. Industrial politics and intensive lobbying were the main tools used to further their interests. During this period, they were successful in lobbying and in creating acceptance for particular public investments in energy and electricity infrastructure (Fridlund, 1999).

The first take-off for engineers started in the 1890s. This take-off and the parallel growth of the industry and engineering education were interrupted by an economic downturn in 1907. Exports were down, unemployment up. The recession culminated in 1909 with general lockouts and strikes. The government decided to hold back further investments in higher education until the end of 1909. An upswing began in the winter of 1909 and continued uninterrupted until the outbreak of the First World War, an event that dramatically changed the conditions for the professionalization process for engineers.

The technological field consolidates: 1916–1939

From 1917 to 1920, the economy experienced inflationary pressure. These conditions helped engineers to organize and to recruit new members quickly. However, the period after the war ended in an economic depression and reduced interest in unions. Hence, the number of members dropped. Still, the unions continued to claim the occupation's general status, level of education, and practical skills. Other professions such as lawyers, medical doctors in the private sector, and consultant engineers could not articulate their interests as clearly toward employers (Torstendahl, 1982b). Despite efforts by the unions and interest groups to find ways to stratify between engineers with different levels of education—thereby excluding some engineers from specific tasks and functions—there was little or no evidence of any effects on the labor market. Exclusion based on education and status was a rather weak strategy among engineers in general (Torstendahl, 1991).

The middle position of many engineers in the labor market made them too weak to found a base for their profession. The various types of engineering expertise and their dependence on business weakened the collective base of autonomous power and of occupational social closure. The low interest exhibited by private businesses in formal competence and education also reduced the capability of engineers to organize (Brante, 1990).

As a result of the price fall and economic crisis after World War I, the industry experienced structural changes and directed greater focus to production effectiveness. Engineers and their inventions pointed investments in the right direction—to a large degree, pointing to research-intensive activities in the heavy industries. The postwar economy led to shortages in some engineering specialties, which pushed salaries upward, especially among engineers in the chemical and arms and ammunition industries. However, engineers working in general public service experienced relatively worsened conditions during the First World War and later the Second World War.

The interwar period led to high unemployment among most engineers (Björck, 2004). The ups and downs of business cycles affected not only the number of employed engineers but also the numbers of applicants and accepted students in engineering education. In 1919, only 44% of all applicants at the KTH and Chalmers were offered admittance; by 1926, the number of applicants had diminished to such an extent that 96% of those who applied were granted entry to engineering programs (Björck, 2004). In 1918, an investigation into salary levels among KTH engineers (and among Chalmers engineers in 1920) concluded that engineering students had declined in social status and that they no longer could be compared with other free occupations such as medical doctors and lawyers. The

economic crises came to a halt in 1928. Although diploma-qualified engineers still comprised a very exclusive group, they were without much unionized power.

Qualitative technological leaps continued during the interwar period. The internal combustion engine, the expanding use of electricity, and developments in flight technology and mechanics technology with new materials all affected the status of engineers. From 1900 to 1932, the total value of industrial production had increased by 204%; however, the number of workers had increased by only 42%, and engineers with a diploma by 41%. The number of engineers in the mechanical industries was stable. The most substantial addition of engineers occurred in the branches of electricity and shipbuilding industries. Unemployment levels in the aftermath of the New York Stock Exchange Crash of 1929 were not as vast as they had been in earlier recessions, and the numbers of applicants and accepted students to engineering education continued to increase, albeit slowly (Björck, 2004).

The recession gave the STF reason to change its internal organization, prompting it to cooperate with other occupational organizations. Together, they formulated ethical codes and improved retirement conditions. They also endeavored to maintain or improve the status of the profession by guarding their title and demanding higher competences for teaching professors at technological institutions (Berner, 1981/2012; Björck, 2004).

The explicit ideological position held by engineers was, in general, apolitical. In reality, the ideology may be defined as “a progressive and pro-technical ideology—within an industrial capitalistic foundation, stable and at the same time dynamically variable” (Björck, 2004, p. 230, my translation). The adjustment of organizations to the technocratic ideologies of social engineering and scientific management (Taylorism) made engineers even more dominant in the technological field. The social-technological solutions to problems, (e.g., increasing the capacity of labor in relation to machines) and the organization of work expanded to issues such as helping workers make budget plans to be able to pay taxes (Björck, 2002). For a society to be organized and for businesses to be systematized and more efficient, it was argued that engineers could not back down from economic and administrative tasks. Engineers’ tasks were broadened to include making economic calculations so as to reduce costs. The power of engineers, based on technocracy, led to segmentation where specialist knowledge was to be used optimally through a differentiation between engineers with different specializations (Berner, 1981/2012).

From 1929 to the 1950s, the rationalistic movement influenced the views of some Swedish engineers; however, it never completely penetrated society or the ideas of all engineers. The rationalistic movement, which related to the ideas of scientific management and Fordism, was linked to a strong productivistic conceptual image of economic growth—an image that corresponded well with what was to become the Swedish model. The engineers argued to expand their jurisdiction outside the purely technical domain (Berner, 1996; Björck, 2004).

Although the demand for both basic and highly educated engineers rose continually during the interwar period, the number of accepted students remained unchanged. A rising problem was that after the First World War, the number of dropouts from the engineering programs had increased. This increase was attributed to overly high expectations from the labor market and to the workload demand placed on students, which also resulted in a prolongation of the time needed to finish with a diploma. The technological university colleges argued that

they would rather increase the quality than the quantity of engineers (Björck, 2004). In 1927, the KTH earned the right to issue doctoral degrees. Chalmers School of Technology earned the same right in 1940. Before the state university colleges were granted the right to issue these types of degrees, the Royal Swedish Academy of Engineering Sciences (IVA), an independent actor in the technological field, had been granted the sole right to do so in 1919 (IVA-aktuellt, 2000).

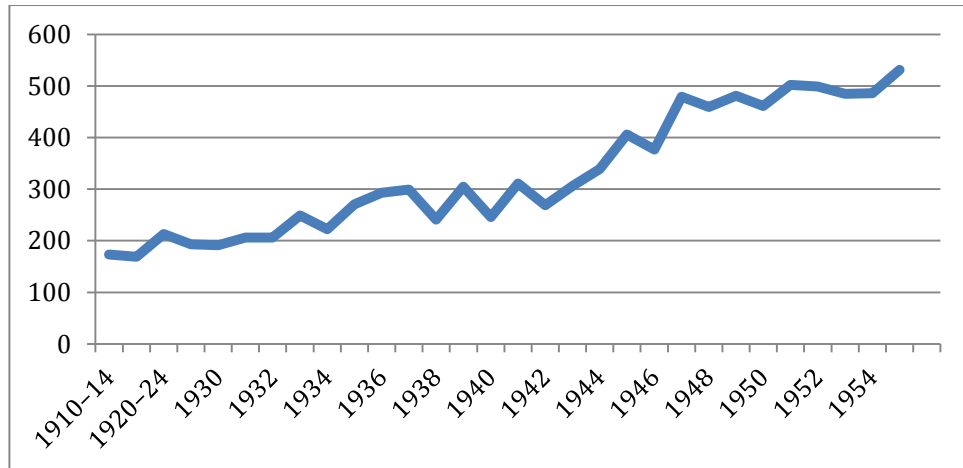


Figure 2. University diplomas in engineering at KTH and Chalmers 1910–1955. Adapted from 1955 års universitetsutredning (1957).

The number of applicants to higher education increased greatly during the First World War. A downturn occurred from 1919 to the beginning of the 1930s, after which the number slowly increased again. As the markets turned upward in 1933, so did the number of diplomas issued (until 1937) and the status of engineers. They could put all their scientific and practical training to use in expanding industries and in building infrastructure. Consequently, employment levels rose, and real wages increased.

Figures 1 and 2 show a steady increase in the number of engineers earning diplomas. From 1910 to 1955, the number of diplomas increased about threefold. However, the number of female engineering graduates was limited to only 1 to 9 per year. Up to 1935, the estimated number of total diplomas was 6700 diplomas, and up to 1955, 11 400 diplomas (1955 års universitetsutredning, 1957). The second highest number of diplomas issued in a particular field was in engineering (21% of all diplomas); it was surpassed only by the number of general diplomas issued in philosophy. The number of diplomas issued in engineering strongly increased from 1942 to 1948. Still, the demand for engineers was much higher than the number of engineers produced. As a consequence, a fivefold increase occurred in the numbers of foreign engineers working in Sweden and of Swedish engineers who had received their diplomas abroad between 1908 and 1939 (Torstendahl, 1975a).

The engineers had positioned themselves as a rather unified body of civil servants in the early 1900s (from 1908 to 1939, engineers doubled their numbers in state administration) (Torstendahl, 1975a). They worked in various technical offices like the state railroad board and in energy institutions like the Swedish energy company, Vattenfall Ltd. Many of them—often in competition with lawyers

and accountants—occupied the highest positions as general directors (Björck, 2004). The increased number of privately employed engineers worked at drawing offices as draughtsmen and became foremen and inventors in bigger industrial corporations, and successful engineers became managers and chief executive officers (CEOs). The numbers of self-employed engineers and engineering consultants also increased. By 1939, the engineering profession had experienced an increased social division of labor according to specializations and level of education, increased wage spread, and increased social status. The process of professionalization of the technological field and engineers was to continue for the next 30 years.

The technological field professionalizes and becomes professional: 1940–1973

From 1940 to 1973, industries became increasingly automated, engineering integrated into other producing organizations, and product markets internationalized. Additional technological institutions were established in the 1940s and 1950s. An incentive from the Ministry of Finance to adopt market-stabilizing measures during recessions by investing in technological research led to the organization of one such institution. The National Commission for Economic Defence and the Organisation for Research Preparedness were established with the support from IVA to organize a national research institute. Together with the development of the welfare state, these actions helped engineers achieve financing for research and technological projects, which in turn improved their status and legitimized their claimed jurisdictions.

In 1943, an investigation argued for an increase of 700 admitted students per year in higher engineering programs from the year 1970. The government of 1946 responded by appointing a committee to examine this issue. Based on the committee's suggestions, the government made forceful investments in higher education and research, producing effects that lasted into the 1960s, and established three new technical university colleges (Lund, Linköping, and Luleå).

Investments in engineering education made in the 1940s and 1950s resulted in updated engineering programs and curricula at lower and higher levels. In the 1960s, the two-year vocational engineering programs became three-year programs. The technological elementary schools developed into upper secondary schools and added a four-year program (and even a five-year program at two schools). The Bachelor of Science in Engineering degree developed from a two-year program into a three-year program.

However, very few technologists continued onto doctoral studies and even fewer finished them. To solve this problem, grants were established to give PhD students a wage similar to that of newly graduated technologists for three years, after which a new diploma could be received, the licentiate.

The *second* take-off for engineers came during this period through the development of the welfare state, which created new markets for engineers and helped the technological field professionalize. The semi-professional upper secondary schools and engineering pupils in institutes expanded rapidly into these new markets (Berner, 1981/2012; Brante, 2010b).

From 1890 to about 1940, the power of engineers relative to other professions constantly increased. However, the period from 1940 to about 1970 was not as successful: it may even be described as stagnate (Torstendahl, 1990). During the 1940s, a conflict arose among the engineers in STF. Younger engineers with lower levels of education wanted to form a union, whereas engineers with diplomas wanted to continue as an interest group. A divide resulted in 1954, leading to the formation of the Swedish Engineering Union (CF) (Berner, 2000). After the Second World War, engineers became more aware, perhaps even self-critical, of their role in society. In 1973, the oil crises and increased international competition created economic stagflation. The technological optimism of engineers was criticized, and engineers lost power to economists and lawyers in high positions in corporations owing to their lack of knowledge of (international) markets and of organizational skills such as negotiating. The loss of power was also related to their inability to organize efficiently in unions. Despite sharing a strong interest in technology and science, they lacked the appropriate amount of common interest to form the political elite (Anselm & Sandström, 1990).

Recent professionalization tendencies in the technological field: 1974–2010

In the early 1970s, several major industries (e.g., steel and shipbuilding industries) could no longer compete in international markets. Many engineers lost their jobs, and the number of engineering graduates dropped. Economists and lawyers continued to be stiff competition for higher positions (such as CEOs and directors-general) in the public sector.

In the mid-1980s, new public management broke through, leading to public organizations becoming more market oriented, transparent, and externally controlled. The autonomy of engineers diminished through this subordination to an increased capitalistic logic, and new demands were placed on engineers and their training. However, with the increased diversity of engineering specializations, successful lobbying from international engineering organizations (i.e., European Federation of National Engineering Associations), and updated higher educational programs, engineers once again regained, to some extent, their earlier position. An argument could be made for a *third* take-off, starting in the mid-1980s and continuing into the 1990s and 2000s, especially in quantitative terms. As shown in Figure 3 below, the number of diplomas issued in engineering has been generally increasing from the early 1990s onward, with the exception of the period from 2005 to 2010 (partly owing to the reorganization of programs and the prolongation from 9 semesters to 10 in 2007). The percentage of engineering graduates who are female increased from 20% in the year 1991–1992 to 39% in the year 2010–2011.

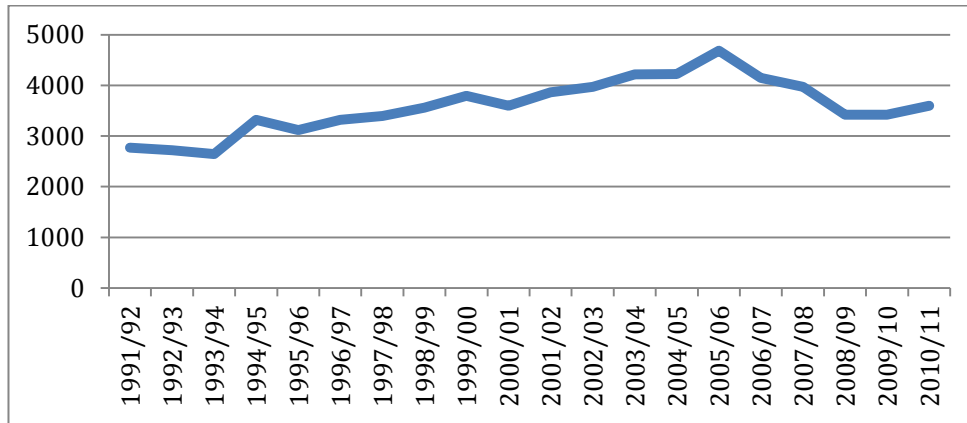


Figure 3. University diplomas in engineering in Sweden 1991–2011. Reprinted from Statistics Sweden, the Education Register and the Occupational Register.

The changed structure of Swedish industries, the internationalization of larger companies, and the Third Industrial Revolution transformed the economies and preconditions for professionalization for engineers in the 1990s (Schön, 2012). New technologies (e.g., the microprocessor) paralleled the new use of knowledge (e.g., biotechnology), and innovations helped foster expansions in the service economies. Although their position relates strongly to the outcomes of the economies at large and the market demand of their services, something of a resurrection of engineers in society has occurred from the 1990s onward.

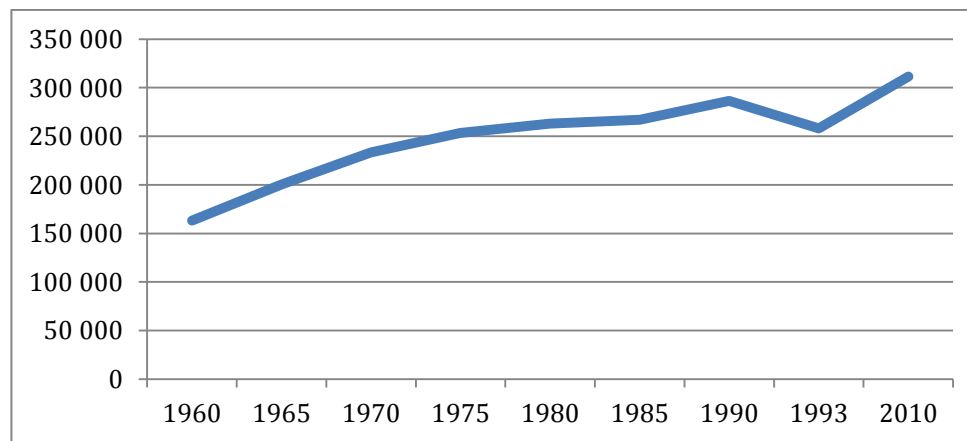


Figure 4. Engineers working in Sweden, 1960–2010. Adapted from Statistics Sweden, the Education Register and Labour Statistics Based on Administrative Sources.

From 1960 to 1990, the number of engineers working in Sweden increased (Figure 4), with the steepest increases occurring from about 1960 until 1970 and from 1985 to 1990. However, from about 1990 to 1993, the number of employed engineers was temporarily but substantially reduced, partly owing to a large number of layoffs in transnational corporations such as Ericsson (the number is also somewhat misleading owing to a change in methodology and a redefinition of the

occupations). The demand for engineers grew slowly but steadily again from 1994 onward; in 2010, the demand and supply of engineers were in balance, and about 307 000 engineers were working in Sweden (Statistics Sweden, 2013).

Despite some turmoil concerning the organization of the unions, the number of members rose dramatically up until about 1980. At that time, the local authorities reduced their investments in technical infrastructure and shifted their focus to the administration of local government services. Union unrest did not subside until 2007 when different unions (with members holding diplomas) joined to form one large union, the Swedish Association of Graduate Engineers (Sveriges Ingenjörer); in 2012, this union had 133 000 members.

Today, the diversity of engineering occupations in the Swedish labor market is larger than ever. Among the newest areas of jurisdictional or functional expansion for engineers in the technological field are nano, ecological, genetic, and financial engineering. Statistics Sweden reports that no fewer than 339 various types of engineers with different levels of education are working today: engineers with a Master of Science in Engineering degree (ca. 105 000), a Bachelor of Science in Engineering degree (ca. 54 000), and a technical upper secondary certificate (ca. 149 000).

Concluding discussion

In Sweden, engineers have experienced both ups and downs throughout their professionalization process. The *first* quantitative and qualitative take-off happened about 1890 and continued until about 1915. The engineers professionalized via improved standardized lower and higher education that attracted the middle classes. Because the majority of the students at engineering university colleges came from the upper classes and had an entrepreneurial history in the technological business, it was easier for them to claim their professional status. However, legitimizing the engineers' claims to status, salaries, and jurisdiction required technological praxis to be based in science and higher education. This legitimization was made possible through the efforts of the state to create higher education, to establish new diplomas, and to update the status of the faculties at universities. These efforts helped engineers to legitimize and gain acknowledgment in society. The engineers' self-conception was a position in society that corresponded to those of medical doctors and lawyers, that is, a profession (Björck, 2004).

A numerical reduction of engineers during the First World War and the interwar period was followed by a *second* quantitative take-off after the Second World War. With the formation of a strong welfare state and more diversified labor markets, the golden age for engineers continued until the 1970s. Engineering education became more scientific with its homogenous scientific core of applied mathematics, science, and rational optimization skills. However, this process paralleled a period of diminished qualitative legitimation and a loss of power among the elites. After some setbacks at the beginning of 1980s, there is evidence suggesting that a *third* quantitative take-off may have started in the mid-1980s (i.e., increases in the number of engineering diplomas issued and the number of engineers employed in the labor market and the emergence of new areas of expertise). The technological field has continued to diversify with new specializations of engineers, and they

seem to have become fragmented to the degree that they now have even less in common than previously in history. Some categories of engineers may continue to gain professional status in the future, whereas others lose theirs and yet others disappear because new technology makes their skills redundant (Freidson, 2001). Future research will benefit from discussing in detail how the Swedish case compares with the professionalization processes of engineers in other nations.

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