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Volume Title: The Demand and Supply of Scientific Personnel

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Volume Publisher: UMI

Volume ISBN: 0-87014-061-2

Volume URL: http://www.nber.org/books/blan57-1

Publication Date: 1957

Chapter Title: THE SUPPLY OF ENGINEERS

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Chapter URL: http://www.nber.org/chapters/c2664

Chapter pages in book: (p. 73 - 92)

CHAPTER IV

THE SUPPLY OF ENGINEERS

IN THE past the engineering profession has been able to grow at a very high rate, and even to raise the educational level of its entrants. The primary reason for this great increase in supply, even with salaries falling relative to the working population, is that it was highly remunerative for a young man to get college training. The additional earnings over those of a high school graduate compensated manyfold for the additional costs of college training.

This is still true, although to a lesser degree. In 1950 the average income of an engineer was about $5,300 per year, whereas the average income of a male with high school education was about $3,200.[1] The additional costs of college training—of which the largest component is four years' postponement of income—would be about 25 or 30 per cent of the earnings of a high school graduate.[2] Since the differential is about 65 per cent, it is still quite remunerative to get college training for engineering, and we may expect numbers to continue to grow.

To this broad conclusion one must make one major qualification: It may not be possible to recruit the same quality of young men in the future, for total demands for highly trained individuals are now both high and growing. We discuss this at a later point.

But this broad answer to the question of future supply is only a beginning. One wishes also to know the future roles of college-trained and other engineers, the extent of graduate training, the appropriateness of the choice of field for specialization, and the like. We turn to these questions.

Entrants to the engineering profession may be classified into two general groups. One group consists of those with four or more years of college training, and holding at least a bachelor's or first professional degree, usually but not invariably from an engineering school. It is this group about which most discussion of additions to the supply of engineers centers. The second group comprises those who have entered the profession with less than four years of

[1] *Census of Population, 1950,* Vol. II, Part 1, Table 129; *Census of Population, 1950,* Special Report P-E 58, *Education,* Table 12.

[2] For a detailed discussion of this problem, see Milton Friedman and Simon Kuznets, *Income from Independent Professional Practice,* National Bureau of Economic Research, 1945.

college training. These engineers may have had several years of college, or have graduated from noncollegiate technical institutes or may simply have been trained on the job. We have already noticed (in Chapter I) that there is some controversy over the proportion of this group which should be called engineers.[3] And yet, even today a substantial part of the engineering profession is drawn from noncollegiate ranks.

In 1940 about 57 per cent of the employed male engineers and the experienced male engineers seeking work had attended college for four or more years (Table 5, Chapter I).[4] About the same division between graduate and nongraduate engineers was found in each of the three main branches of engineering: civil, electrical and mechanical. In the remaining branches (among which chemical engineers were the largest single group), the college-trained portion was somewhat higher. In 1950, after what was apparently a large influx of nongraduates into the engineering profession during and after the war, the proportion of engineers with four or more years of college dropped to about 55 per cent.[5] Graduate engineers accounted for 53 per cent of mechanical (including aeronautical) and civil engineers, and 55 per cent of electrical engineers. The remaining branches again had a larger proportion of graduate engineers, 61 per cent.

1. *College-Trained Engineers*

The dominant method of preparing for the engineering profession is through college training, usually at an engineering school. The future number of engineering graduates will be determined by the numbers of persons reaching college age, the proportion of such persons attending college, and the proportion of the latter choosing to study engineering. The number of persons reaching college age will increase substantially over the next decade and a half—by almost two-fifths from 1955 to 1965 and almost three-fifths by 1970 (see Chapter V). The proportion of college-age population attending college has risen more or less steadily over time and there is

[3] See also Dael Wolfle, *America's Resources of Specialized Talent,* Harper, 1954, pp. 95, 96.

[4] With definitions comparable to those in 1950. The percentage as reported in the 1940 census was slightly higher—about 61 per cent (see Chapter I, note 11).

[5] Special unpublished tabulation of the census manpower occupations card file for the Bureau of Labor Statistics and sponsored by the National Science Foundation. Dael Wolfle suggests slightly different percentages for 1940 and 1950: 56 and 58 per cent, respectively (Wolfle, *op. cit.,* pp. 95–96).

little reason to believe that it will not continue to do so, provided sufficient facilities and staff are made available. If there were no change in the distribution of college students by area of specialization, these two factors would produce a very substantial increase in the future number of engineering graduates.

The proportion of college graduates specializing in engineering is the difficult and interesting component of supply. The number of first degrees in engineering grew continuously in each half-decade between 1900 and 1950, reaching an all-time high of 159,600 in 1946–1950 (Table 30). The ratio of first degrees in engineering to

TABLE 30

Number of Bachelor's and First Professional Degrees in Engineering and Ratio to Total Bachelor's and First Professional Degrees, 1901–1955

	Number of First Degrees in Engineering	*Annual Average Number of Engineering Degrees*	*Per Cent of Total First Degrees*
1901–1905	4,900	980	3.3
1906–1910	7,500	1,500	4.3
1911–1915	12,500	2,500	6.0
1916–1920	20,100	4,020	9.3
1921–1925	37,100	7,420	10.3
1926–1930	38,800	7,760	7.0
1931–1935	54,800	10,960	8.0
1936–1940	62,600	12,520	7.6
1941–1945	68,500	13,700	8.8
1946–1950	159,600	31,920	11.3
1951–1955	143,118	28,624	8.9

Source: Dael Wolfle, *America's Resources of Specialized Talent,* Harper, 1954, pp. 292–295; *Earned Degrees Conferred by Higher Educational Institutions,* Office of Education, Circulars 418 and 461, December 1954 and 1955.

all first degrees has also shown a rising trend but with considerably more irregularity. The ratio increased from 3 and 4 per cent in the first decade of this century to 9 to 11 per cent since 1940. There have been two bulges in this trend, one after each war, which were followed by a temporary decline in the relative importance of engineering degrees, although never back to prewar levels. After the decline in the late twenties, the ratio started rising again, and the same phenomenon is occurring now.[6]

For lack of data, we cannot discuss in detail the degree of future attractiveness (financial or otherwise) of engineering as

[6] *Ibid.*, p. 98; also *Engineering Enrollments and Degrees, 1952,* Office of Education, Circular 364, 1953, pp. 1 and 2.

compared with other occupations that college graduates engage in. In Chapter II, where we compared engineering incomes and incomes of other occupations, we found in general a fall in relative incomes of engineers over the last twenty-five years. But these comparisons were largely restricted to the entire labor force, on the one hand, and to the major independent professions, on the other. The former group is essentially not college-trained and the latter's training usually exceeds by several years the standard four-year engineering program. While these comparisons were valid for the purpose then at hand, they yield little information on the changes in engineering income relative to those in other occupations which most entering college students consider alternatives to engineering. For this comparison we would need data on incomes over a reasonably long period of those occupations in which most college graduates engage or, more precisely, on incomes of graduates themselves. And such data are not available.

For the very recent past, Endicott's data on starting salaries of college graduates (Chapter II, and Appendix A) show no important change in salaries of newly graduated engineers relative to other new graduates entering the business world since 1948. But starting engineers throughout this period commanded a higher salary than other graduates.[7] Such a premium is likely to exercise a continuing incentive for students to shift towards engineering.

Pending the accumulation of wider information on incomes of college graduates, we may employ simple extrapolations of the engineering degree ratio to derive at least rough orders of magnitude of the likely number of future engineering graduates. Under this procedure, of course, the major part of the expected increase in engineering graduates will be a result of the increases in college age population and college enrollments.

In Appendix D we develop several projections of the future number of engineering graduates to 1970. We there use both expected total population and expected male population[8] reaching college graduation age as bases for applying ratios of graduation age population receiving degrees and ratios of degree recipients in engineering. In essence our conclusions are that if the proportion of the graduation age population receiving degrees rises only

[7] For example, in 1954 the average starting salary for new engineering graduates was $345, compared with $315 for graduates in accounting, $314 for graduates entering sales work; $310 for general business trainees, and $328 for other fields (see Appendix A).

[8] Nearly all engineers are males.

moderately, and if the ratio of engineering degrees to total first degrees remains essentially at present levels (or increases very slightly), the number of engineering graduates will reach about 35,000 in 1960, almost 50,000 in 1965, and 60,000 or more in 1970. If the proportion of graduation age population receiving degrees increases to 1970 at the annual rate it grew between 1930 and 1950,[9] and if the proportion of degrees accounted for by engineering graduates rises at the 1930–1950 annual rate, there will be 40,000 or more engineering graduates in 1960, 60,000 or more in 1965 and as many as 80,000 to 90,000 in 1970. We may contrast these estimates with the annual average number of first degrees in engineering during the twenties of almost 8,000; during the thirties, of 12,000; during the forties, of about 22,000; and during the early fifties, of about 29,000.

It would be desirable, we repeat, to examine the determinants of occupational choice among college students, but we shall not enter upon this large subject here. But it should be emphasized that the roles of income, stability of employment, subsequent breadth of choice of industry or type of work, and similar factors have not yet been examined quantitatively.

2. *Graduate Degrees in Engineering*

The number of master's degrees in engineering has risen substantially over the last three decades, from less than a thousand per year in the twenties to four to five thousand per year in the late forties and early fifties (see Table C-6, Appendix C). Surprisingly, there has been no upward trend in the ratio of master's degrees awarded each year to bachelor's degrees awarded in the preceding year. Since the late twenties, this ratio has fluctuated about the 10 per cent level, rising above it during the early thirties, falling substantially below during the war, rising above it again during the first postwar years, but returning to it once again in the early fifties.[10] One might expect the proportion of engineers with bachelor's degrees going on to a year of graduate training to rise

[9] We exclude veterans from the data on population and degree recipients in 1950 (see Appendix D).

[10] See Appendix Table C-6; also Henry H. Armsby, "Current Trends in U.S. Colleges and Universities: Production of Engineers" and Herbert S. Conrad, "Current Trends in U.S. Colleges and Universities: Production of Scientists," both in *Symposium on Scientific and Specialized Manpower*, Department of Defense, Research and Development Board, June 15–16, 1953, pp. 23, 29–30. Armsby uses the 10 per cent ratio in his projections of master's degrees in engineering, while Conrad employs a 9.8 per cent ratio.

somewhat in the future, in view of the growing importance of the research function among engineers and the great increases in demand for engineering services in the aeronautical, nuclear energy and electronic fields. But the past growth in these areas does not seem to have had any perceptible influence in this direction.

The number of engineers obtaining the Ph.D. degree has always been small, reaching an annual rate of more than 100 only after World War II (Table 31). By the early fifties, about 550 doctor's

TABLE 31

Number of Doctor's Degrees in Engineering, 1911–1955

	Number	*Average Annual Number*	*Ratio to Number of Bachelor's Degrees*
1911–1915	10	2	0.1
1916–1920	20	4	0.1
1921–1925	60	12	0.2
1926–1930	150	30	0.4
1931–1935	340	68	0.6
1936–1940	320	64	0.5
1941–1945	230	48	0.3
1946–1950	1,180	236	0.7
1951–1955	2,763	553	1.9

Source: Dael Wolfle, *America's Resources of Specialized Talent*, Harper, 1954, pp. 294–295, 300–301; *Earned Degrees Conferred by Higher Educational Institutions*, Office of Education, Circulars 418, 461, December 1954 and 1955.

degrees in engineering were being awarded annually. Unlike the situation with regard to master's degrees, the ratio of doctor's degrees in engineering to bachelor's degrees has shown an upward movement over time, rising from 0.1–0.2 per cent in 1911–1925 to 0.4–0.6 per cent in 1926–1940, and to 0.7 per cent in 1946–1950. In the early fifties this ratio reached 1.8 per cent, although a portion of this rise was a reflection of the very large college graduating classes several years earlier, classes larger in size than those now being graduated. Although the number of engineering doctorates being awarded is still small, so small in fact that they probably can be disregarded in analysis of the general engineering supply problem, they undoubtedly are of importance in certain highly specialized fields and for additions to college teaching rolls. It is likely that the growth not only in the numbers of doctorates but also in the proportion of recipients of bachelor's degrees going on to Ph.D. training will continue.[11]

[11] Engineering doctorates now account for a perceptible proportion of all doctorates, rising from about 1 per cent of all doctorates around 1920 and

3. *The Distribution of Bachelor's Degrees by Field*

In 1952, the most important field of specialization for new engineering graduates was mechanical engineering, accounting for about a quarter of all bachelor's degrees awarded in that year (Table C-7, Appendix C). The next largest fields were electrical engineering, with slightly more than a fifth of all degrees, and civil engineering, with slightly less than a fifth. Chemical engineers represented almost a tenth of all new graduates; and mining engineers, only a little more than 1 per cent. About a quarter of all first degrees in engineering could not be allocated to specific fields or were in minor engineering fields.

The proportions of all first degrees in engineering accounted for by civil and electrical engineering degrees followed essentially similar paths of movement after the late twenties: a continuous decline through the thirties, and a rise during the forties. The share of civil engineering degrees experienced a rise from 1941 to 1946, a drop during the next two years, and a further substantial rise from 1948 to 1952. The share of electrical engineering degrees was fairly stable (at its trough level) through the war and rose sharply from 1947 to 1950, with a decline in the next two years.

Degrees in chemical and mechanical engineering followed almost the reverse pattern: their share rose through the thirties and into the war, and declined after the war. Chemical engineering degrees followed precisely this path, while mechanical engineering degrees differed slightly in two respects. Their share remained at a constant level through much of the thirties and started to rise after 1938, reaching a peak in 1947.

The share of engineering degrees accounted for by mining engineering was extremely small throughout this period and declined steadily with almost no reversals.

Data are available on the relative earnings of engineers in the various specialties for benchmark dates during the period 1929–1946. These data permit us to give at least a broad answer to the question of whether the distribution of engineering students among the major fields responds over time to the changes in demand for specialists in the several fields. In principle, one would expect occupational choice to be largely determined by the discounted values of expected life earnings in alternative occupations, compared with the discounted costs of entering these occupations.

2 per cent around 1930 to 5.6 per cent in 1946–1950 and 6.7 per cent in 1951–1953 (Wolfle, *op. cit.*, pp. 298–299).

Among engineering fields, educational costs are approximately equal, so that choice should be a function of earnings alone. We here use the movement of median salaries of engineers with 9 to 11 years' experience as an index of the movement of the discounted life earnings of engineers in the several specialties.[12]

If entrants to the engineering profession are influenced in their choice of field by relative changes in present values of life earnings in the several engineering fields, the proportion of entrants in each field will vary in response to salary differentials. If nothing else changed and if sufficient time elapsed to permit this equilibrating process to reach completion, salaries among the fields would approach equality or at least reach some stable relationship whose differentials would compensate for the "net disadvantages" of each specialty. Thereafter the distribution of new entrants would be such as to maintain this equality or stable relationship in earnings. However, relative demands for the various specialties have shifted so much in this period, that one would not expect a long-run equilibrium to be attained.[13] As a result we are forced to limit our analysis to investigation of the degree to which the distribution of new entrants responded to changes in salary differentials.

In Table 32 we rank the four largest engineering fields in terms of percentage increase in salary in each field and in terms of the percentage increase in the share of first degrees in each field.[14] Since

[12] In Appendix A, we develop data on salary level at benchmark dates between 1929 and 1946 of three groups of engineers in each major field: those with less than a year's experience, those with 9 to 11 years' experience, and those with 30 to 34 years' experience. Changes in salary rates at each of these experience levels will be reflected in changes in the discounted value of life earnings, with weights related to the reciprocal of the discount factor at each experience level. Since the discount factor for our group of older engineers is quite large, the effect of differential changes in salary rates at this experience level is relatively small. The weight of differential movements in salary rates of younger engineers is much larger but the differences in salary movement among this group for the period under study are quite small. Accordingly the relative changes in intermediate engineers' salary rates probably provide a reasonable index of shifts in discounted values, since the differences in salary movement for this group are substantial and the discount factor is only moderate.

[13] But the salary differentials among the major fields have declined perceptibly since 1929. Thus in 1929 the ratio of the median salary of graduate engineers with 9 to 11 years' experience in the highest paying field to that in the lowest paying field was 1.28. In 1946, the corresponding ratio was 1.16 (see Appendix A).

[14] The salary data combine the information in Appendix A on salary rates for graduate engineers and for all engineers on the assumption that rates for both groups changed in parallel fashion. In the sources from which the degree data are obtained, degrees in minor and "other" engineering fields account for

an engineer decides on his professional field some time before he receives his degree, shifts in degrees should lag behind changes in prospective income. The lag is probably less than a full four years, since there is substantial flexibility in the early years of engineering school. An engineering student is not heavily committed to a field until his second or, more likely, his third year at college. Accordingly, the comparisons in Table 33 generally involve a lag of two years between the initial or terminal year for income data and the

TABLE 32

Ranking[a] of Engineering Fields by Percentage Increase in Base Salary of Engineers with Nine to Eleven Years' Experience, and by Percentage Increase in Share of First Degrees, Various Periods, 1929–1948

Salaries, 1929–1934	*Degrees, 1932–1936*	*Salaries, 1934–1939*	*Degrees, 1936–1941*	*Salaries, 1939–1946*	*Degrees, 1941–1948*
Civil	Chemical	Mechanical	Mechanical	Civil	Civil[b]
Electrical	Mechanical	Chemical	Chemical	Mechanical	Electrical
Mechanical	Civil	Electrical	Electrical	Electrical	Mechanical
Chemical	Electrical	Civil	Civil	Chemical	Chemical

[a] Ranked from high positive increases to high negative increases.
[b] The average share for 1947 and 1949 substituted for the share for 1948.
Source: *Salaries:* Appendix Tables A-9 and A-10.
Degrees: Appendix Table C-7.

corresponding initial or terminal year for degree data, e.g. 1934–1939 for incomes and 1936–1941 for degrees.[15] An inspection of the data suggests that a lag of a year more or less than the one we used would yield similar results.

For the last half of the thirties and again for the first half of the forties, there is a high positive association between changes in salary differentials among the major fields and lagged changes in

roughly about a fifth of all degrees granted each year since 1932; such degrees are not included in the degree calculations, although all engineers in minor fields are reclassified into one of the five major fields in the income data. The major field of mining engineering is not included in the analysis; this field accounted for a very small proportion of all first degrees in engineering (less than 4 per cent since 1934 and less than 3 per cent since 1938) and this share declined almost continuously over the period under study. Minor changes in the number of such degrees reported or in the classification of such degrees as between mining engineering and minor engineering fields could have a major impact on the share of total degrees accounted for by this field, since the level of the share is so low. Accordingly, it seemed advisable to restrict the analysis to the four large fields, each of which accounted for at least 9 or 10 per cent of first degrees.

[15] Since 1931 data for degree shares were not available, 1932 figures were used.

the distribution of degrees. The ranking of fields by percentage changes in salaries for 1934–1939 is matched precisely by the ranking of fields by percentage changes in degree shares for 1936–1941. The association between the two rankings is not perfect for 1939–1946 (1941–1948 for degrees) but is still high, with only one reversal of rank.[16]

In the first period (1929–1938 for salaries and 1932–1936 for degrees), there is essentially an inverse relationship between the two rankings (the rank correlation coefficient is —0.8). Indeed, if we combine civil and electrical engineering, on the one hand, and mechanical and chemical engineering, on the other, we obtain an inverse relation; degrees in these two pairs of fields, it will be remembered, had different patterns of change after 1929.

But in this earliest period (and in this period alone) average incomes of engineers in different fields are not fully measured by median salaries of employed engineers. Of all the years for which income data are available, only in 1932 and 1934 was there substantial unemployment in the engineering profession. In 1929 and again in 1939, and still again in 1946, the reported level of unemployment was under 1 per cent. In 1932 and 1934 unemployment was reported at 10 and 9 per cent respectively.[17] Measurement of changing economic incentives in this period, then, must take account of the degree of likelihood that a new graduate would obtain employment in his chosen field.

If the four major fields are inversely ranked by their percentage of unemployment in 1934, the following list is obtained: chemical, mechanical, electric and civil.[18] This ranking is the same as that for changes in degree shares for 1932–1936, except for the reversal of electric and civil engineering. If changes in degree shares are taken for 1932–1935, the largest percentage decline in share of total

[16] The coefficient of rank correlation is 0.8. The same coefficient holds for a comparison of ranks for 1939–1943 (1941–1945 for degrees). In the two periods running into World War II, mechanical engineering degrees are out of rank; this exception may be due to the exclusion from the degree data of minor engineering fields that properly belong in this category. The differences in percentage change in salaries between 1943 and 1946 are too small to permit analysis of the responsiveness of degree distribution.

[17] *Employment and Earnings in the Engineering Profession, 1929 to 1934,* Bureau of Labor Statistics, Bull. 682, 1941, p. 93.

[18] Although the unemployment rate for electrical engineers in 1934 was only fractionally higher than that for mechanical engineers (7.4 per cent as against 7.3 per cent), "increases of nonengineering employment [between 1929 and 1934] were particularly important to electrical engineers" (*Employment and Earnings in the Engineering Profession, 1929 to 1934,* pp. 52, 93).

first degrees is in civil engineering, and the ranking of changes in degree shares is identical with the inverted ranking of fields in terms of unemployment.

It appears clear, therefore, that economic incentives have played an important role in attracting engineering students toward those fields in which demand has been high and increasing.[19]

4. *Other College-Trained Entrants into the Engineering Profession*

A substantial component of the current supply of college-trained engineers consists of persons trained in nonengineering fields who enter the engineering profession upon graduation or at some later time. The largest single group of such entrants consists, of course, of persons who majored in the natural sciences while in college. The remainder are scattered widely over other fields of college training.

Estimates have been made by the Commission on Human Resources and Advanced Training of the occupational distribution in 1953 of all living college graduates (under the age of 70) who had trained in each major field of undergraduate study.[20] By combining these estimates with other estimates by the Commission of the number of living college graduates (under 70) in each of these fields,[21] we are able to determine the relative magnitude of this component of college-trained engineers.

According to these estimates, about 28,000 persons who had received bachelor's degrees in the natural sciences were actively engaged in engineering in 1953. About 12,000 of these were trained in the physical sciences (primarily physics and mathematics), about 9,000 in chemistry and about 7,000 in the earth sciences (primarily geology).[22] There were also another 30,000 persons trained in other fields (except engineering) who were functioning as engineers in 1953. The largest single group of these were the 10,000 persons who had received bachelor's degrees in education,

[19] If we plot the data underlying Table 32 on a scatter diagram, it appears that an engineering specialty with a percentage increase in salary 10 per cent greater than that for all others will increase its share of degrees by about 6 or 8 per cent. However, we are not inclined to press the precision of this estimate, because we have only eight observations (four in each of two periods), and one of these deviates considerably from this line of relationship.

[20] Based on a survey of the occupational distribution in 1953 of the graduates of 1930, 1940, and 1951 of two large universities (see Chapter III for details).

[21] Wolfle, *op. cit.*, pp. 295, 304.

[22] "Of the 31 per cent of chemistry undergraduates who entered other professions 26 per cent went into medicine and most of the rest into engineering. . . . Nearly all earth scientists who entered other professions became engineers" (*ibid.*, p. 57).

presumably in science and mathematics teaching. The remainder were distributed widely over other fields of study.

The 58,000 engineers with college training in fields other than engineering comprised about 9 per cent of the total number of engineers and about 16 per cent of the number of college-trained engineers in 1953.[23] To put it another way, the number of engineers with college training outside of engineering was equal to almost one-fifth of the number of active engineers with engineering degrees.[24]

A second study, conducted jointly by the National Scientific Register and the Commission on Human Resources and Advanced Training, deals with the occupational distribution in 1952 of college graduates of June 1951 and was based on a 20 per cent sample of all 1951 graduates. It was found that about 71 per cent of the 41,000 persons who received bachelor's degrees in engineering in 1951 (or 29,100) were actively engaged in engineering work in 1952 (see Chapter III for further details). These engineers, however, represented about 93 per cent of those graduate engineers with civilian jobs in 1952. In addition, about 5,000 persons who received bachelor's degrees in other fields in 1951 were engaged in engineering in 1952. The largest single group, again, consisted of natural science degree holders (about 2,000); the remainder were scattered over the remaining fields of study, including about 700 with degrees in education and 900 with degrees in business and commerce.[25]

Thus the number of bachelors in fields other than engineering who entered the engineering profession within a year after graduation equalled almost one-eighth of all recipients of first degrees in engineering in 1951, and about one-seventh of all 1951 college graduates who immediately entered engineering. And these nonengineering graduates represented an addition of about one-sixth to the engineering graduates of 1951 who entered the profession in their first year following graduation. Indeed, the total of the nonengineering graduates who entered the profession, the recipients of advanced engineering degrees, and the recipients of bachelor's degrees in engineering who immediately entered engineering work amount to about 7 per cent more college graduates starting

[23] *Ibid.*, p. 96.

[24] Some of the former, of course, had received graduate training in engineering (*ibid.*, p. 39).

[25] Based on unpublished tabulations for the National Science Foundation. Similar results were found for holders of master's degrees.

engineering work in 1951 than the number who received bachelor's degrees in engineering in that year.[26]

Accordingly, it is reasonable to expect that, if there is in the future a rising demand for engineering services, the number of nonengineering graduates entering engineering work will constitute an addition of 10 to 15 per cent to the number of bachelor's degrees in engineering. This would suggest that perhaps 4,000 to 6,000 college graduates in fields other than engineering will enter engineering work in 1960 and perhaps 6,000 to 12,000 in 1970.[27]

5. *Limitations on the Supply of College-Trained Engineers*

Unless the able young men find it more difficult than less able men to enter college—that is, unless college selection is perverse—one would expect a rise in the proportion of people entering college to be associated with a fall in their native capacity. But the important questions are: how much (if at all) does the quality decline; and can any one large profession insulate itself from a general decline?

On the former question—the average level of ability of all college entrants—there is no good historical information. Writers on this subject, once they reach a critical age, are inclined to observe a decline over time, and it would be improper to dismiss this as pure nostalgia. But one may conjecture that changes are small: the vast proportion of additional college students will come from intelligence levels which largely overlap those already attending, and presumably still with a minimum intelligence score of about 110.

According to Wolfle, graduating engineers place third out of the twenty major fields of undergraduate study, when ranked according to median scores on intelligence tests.[28] Students in the physical sciences and in chemistry rank higher, with median scores of 127 and 125, followed by the median score of 124 for engineers.[29] The remaining groups vary from a median score of 124 for law and 123 for English down to 113 for home economics and 112 for physical education. Thus it might appear that any substantial expansion of

[26] But 8 per cent less than the number receiving engineering degrees at all levels in 1951 (Wolfle, *op. cit.*, p. 63).

[27] The numbers are unlikely to be higher than these because the high projections of engineering degrees are based on a rate of growth in the ratio of engineering to total first degrees that involves some diversion of students to the engineering field during college, rather than afterward.

[28] Wolfle, *op. cit.*, p. 199.

[29] The scores are based on the Army General Classification Test scale (*ibid.*, pp. 317–320).

engineering enrollments, relative to other enrollments, would involve recourse to students of lower caliber.

But the range of median scores among fields is quite small, while the range of scores within each field is very large. While median scores for all fields range from 127 to 112 (127 to 118 for the top 18 fields), the middle 50 per cent of engineering graduates range from 132 to 117 and the middle 80 per cent, from 140 to 110. In 17 of the 20 fields, the top 50 per cent of the graduates rank higher (in many cases, considerably higher) by this measure than the lowest 25 per cent of engineering graduates, and the top 25 per cent, higher than the median score for engineers. Even in the two lowest-ranking fields (home economics and physical education), the top 25 per cent place higher than the lowest 25 per cent for engineers.

On the basis, then, of general intellectual aptitude, there should be no large deterioration in quality of engineering students with a moderate expansion of the proportion of undergraduates specializing in engineering, providing the level of demand and resulting financial incentives warrant such an expansion. It will be more difficult, however, to maintain the same share of engineers of the highest abilities. There may be difficulties in terms of limitations of specialized abilities or quality and breadth of high school training or nonmonetary incentives, but about these we know little. Indeed, further investigation of the limits of the supply of college-trained engineers should focus precisely on such questions.

6. *Nongraduate Engineers*

The component of the supply of engineers about which we know the least and about which controversy flourishes is that composed of persons without a college degree. As we have seen, two-fifths or more of the profession (by census definitions) fell into this category in both 1940 and 1950.

We can roughly estimate that nongraduate engineers entering the engineering profession in the twenties accounted for about two-fifths of the gross number of entrants during that decade or, in other words, that they represented an addition of perhaps two-thirds to the number of engineering graduates entering the field.[30] In the thirties and again during the forties, nongraduates accounted for about one-third of total gross accessions and equalled about one-

[30] *Employment Outlook for Engineers*, Bureau of Labor Statistics, Bull. 968, 1949, p. 41; Appendix E.

half of the number of entering graduates.[31] Clearly, nongraduates have formed a large component of the supply of new engineers over the last thirty years. There is no reason to believe that this component of supply will diminish rapidly in the near future. Accordingly, any attempt to measure the current or prospective supply of new engineers that is restricted to engineering and other graduates considerably understates the magnitude of new accessions. If the ratio of nongraduates entering the profession to new engineering graduates remains at the same level as in the last twenty years (or declines only moderately), we may expect the former to reach 15,000 to 20,000 per year around 1960 and 30,000 or more around 1970.

In view of the quantitative importance of nongraduates in the engineering profession, it is surprising that so little is known about the ways in which they enter the profession and the kinds of functions they perform. It is, of course, hard to collect information about nongraduate engineers. It is obviously simpler to work with data on engineering degrees granted and even to collect data on the work history of recipients of such degrees. It is also hard to define an engineer. Although it is generally assumed that any engineering graduate (or indeed any college graduate) who reports himself as engaging in engineering work is an engineer, there is much less unanimity about nongraduates who so report themselves. In fact, the disagreement with regard to the 1950 census count of engineers essentially centers about the question of what proportion of the nongraduate engineers there reported were engineers and what proportion were really subprofessionals. With no clear definition of what constitutes an engineering position, the task of collecting information on the number, duties and means of entrance of nongraduate engineers becomes extremely difficult.

It is clear that information about nongraduates would help us greatly in measuring supply. Perhaps some limited field studies of engineering staffs of corporations employing large numbers of engineers might yield sufficient initial data on the ways in which both employers and employees define engineering work to clarify the definitional problem. Further questionnaire studies, then, could obtain direct information on the numbers of nongraduates, the duties they perform, and the ways in which they entered the profession.

[31] *Employment Outlook for Engineers,* pp. 41, 87; Appendix E.

Even though our understanding of the character of the nongraduate component is very limited, some information is available from special tabulations of the 1950 census and other sources. Of the 45.5 per cent of employed engineers with less than four years of college in 1950, more than one-third had attended college for some period of time, another one-third had completed four years of high school, and the remaining slightly more than one-quarter had completed less than four years of high school (Table 33).

TABLE 33

Percentage Distribution of Employed Engineers by Age and Years of Schooling, 1950

YEARS OF SCHOOL COMPLETED	TOTAL EMPLOYED	AGE *14–19 Years*	*20–24 Years*	*25–34 Years*	*35–44 Years*	*45 Years and Over*
High School						
1–3 years	12.2	0.1	0.4	1.9	3.3	6.6
4 years	15.7	0.1	0.9	4.6	4.7	5.3
College						
1–3 years	17.6	[a]	1.1	5.6	5.4	5.5
4 years	40.2	[a]	2.8	16.5	9.9	11.0
5 or more years	14.3	[a]	0.7	5.8	4.1	3.7
Total	100.0	0.3	6.0	34.4	27.3	32.0

[a] Less than 0.05 per cent.
Note: Items do not necessarily add to totals because of rounding.
Source: Appendix Table F-2.

The 1950 census count of engineers included younger men who reported themselves as engineers but who had little or no college training. The 1940 census specifically excluded from the technical engineering category any person under 35 who had completed less than four years of college training; it has been estimated that 20,500 persons were excluded from the engineering category by this ruling. Had the 1950 census employed the same definition, between 75,000 and 80,000 fewer engineers would have been reported. However, the very young engineers (by 1950 census definitions) with very little schooling do not bulk large in this group (Table 33). Thus only 1.5 per cent of those counted as engineers in 1950 were under 25 years of age and had completed no years of college, and only 2.6 per cent were under 25 and had completed less than four years of college. The nongraduates were most important in the older age groups. Almost five-sixths of those engineers with less than four years of high school were 35 or older, and more than half were 45 or older.

The greater age of non-college-trained engineers is of course due primarily to the fact that competent training in applied science is acquired more rapidly by formal education than by experience. Moreover, there will be relatively few college-trained engineers who transfer to this work after (say) the age of forty, but there are a considerable number of non-college-trained workers who do so.

The younger engineers with little or no college training were fairly equally represented in nearly all of the branches of engineering (Table 34). Of all the specialities, chemical engineers had the

TABLE 34

Per Cent of Employed Engineers under 25 and under 35 Who Had Completed No Years of College and less than 4 Years of College, by Field of Specialization, 1950

FIELD OF SPECIALIZATION	NO COLLEGE TRAINING		LESS THAN 4 YEARS OF COLLEGE	
	Under 25	*Under 35*	*Under 25*	*Under 35*
Aeronautical	0.9	9.4	1.9	21.9
Chemical	0.9	4.0	1.6	7.5
Civil	2.2	7.5	3.6	13.3
Electrical	1.9	9.3	3.4	16.9
Industrial	1.0	10.2	1.7	18.1
Mechanical	1.2	7.8	2.1	14.0
Metallurgical	2.5	10.2	3.6	16.7
Mining	1.5	6.7	2.1	10.3
Other	1.1	7.7	2.0	15.5
All engineers	1.6	8.0	2.7	14.8

Source: Appendix Tables F-2 to F-11.

smallest proportion of those under 35 years of age who had not attended college or had completed less than four years of college. The highest proportions of those under 35 with no college training and with less than four years of college training were found in industrial, metallurgical, aeronautical and electrical engineering.

When we compare the proportions of all nongraduates (not merely those under 35) in the various engineering fields in 1950, we find that the three largest fields (civil, electrical, and mechanical, including aeronautical) were all at about the same level, with 45 to 47 per cent having completed less than four years of college (Table 35). A fourth group, comprising chemical, industrial, and mining and metallurgical engineering, had only 38 per cent with less than four years of college; within this group, chemical engineering had the lowest proportion of nongraduates, only 30 per cent. A final category of engineers "not elsewhere classified" was divided equally between graduates and nongraduates.

TABLE 35

Percentage Distribution of Employed Engineers by Field of Specialization and Years of Schooling, 1950

Field of Specialization	*Less than 4 Years of College*	*4 or More Years of College*
Civil	47.2	52.8
Electrical	45.0	55.0
Mechanical (including aeronautical)	47.1	52.9
Chemical, industrial, and mining and metallurgical	38.3	61.7
Other	50.0	50.0
All engineers	45.5	54.5

Source: Appendix Tables F-2 to F-11.

It is difficult to compare the changes in the graduate-nongraduate composition of the several fields between 1940 and 1950. There were some changes in definition among the fields. Also, in 1940 all engineers were classified into one of six fields, while in 1950 a substantial number of engineers were classified into a seventh category, viz. engineers "not elsewhere classified." [32] The 1940 counterpart of each of these engineers was apparently included in one of the major engineering fields in the 1940 census tables.[33]

However, if we disregard this category and deal solely with the groups we can identify in both 1940 and 1950, we find that the proportion of nongraduates increased by between 6 and 9 percentage points in each field over the decade. The much smaller

[32] In 1940, the education data on engineers were presented in terms of three fields, civil, electrical and mechanical, and a fourth which combined chemical, industrial, and mining and metallurgical. An examination of the index of occupations used in the 1940 census revealed that aeronautical engineering was then treated as a component of mechanical engineering. The unpublished age-education tabulations of the 1950 census present separate data for civil, electrical, mechanical, chemical, industrial, mining, metallurgical, and aeronautical engineering and for 72,000 engineers not elsewhere classified. We can add aeronautical engineering to mechanical engineering and combine chemical, industrial, mining, and metallurgical engineering to approximate the 1940 classifications, but we are still left with the n.e.c. engineers whom we are unable to distribute among the already-specified fields.

[33] Thus acoustical engineers in 1940 were considered civil engineers but fell into the n.e.c. category in 1950.

increase[34] in the proportion of nongraduates in the profession as a whole resulted from the fact that these substantial increases in the nongraduate proportion within each field were largely offset by the more rapid growth of the fields with a high proportion of graduates. Thus the combined group of chemical, industrial, mining and metallurgical engineering, with only 29 and 38 per cent nongraduates in 1940 and 1950, increased by 176 per cent over the decade, while both civil and mechanical engineering, with 41 and 47 per cent nongraduates in 1940 and 1950, grew only 41 and 57 per cent respectively during the ten-year period. Electrical engineering, with 38 and 45 per cent nongraduates in 1940 and 1950, grew by 85 per cent over the decade.

Finally, we may add a word about the functions most typically performed by nongraduates. In a 1946 study the Engineers Joint Council obtained data on the distribution of professional society members (with differing educational backgrounds) among approximately thirty different functions.[35] These data suggest that nongraduates were distributed widely among the functions performed by graduates and, with one or two exceptions, in rather similar proportions. There were some differences which are enlightening but in almost no case was there any indication that nongraduates cannot or do not perform functions engaged in by persons with bachelor's or higher degrees in engineering.

The largest number of privately employed engineers are engaged in technical administration-management; about one-third of both graduates and nongraduates are so occupied.

The following five functions (in order of importance) accounted for another third of privately employed society members: design, development, applied research, construction supervision, and university or college teaching. About the same proportion of nongraduates were engaged in design activities as of members with bachelor's degrees (15 to 17 per cent as against 18 per cent); for holders of doctorates the figure was only 7 per cent. A smaller proportion of nongraduates were active in development and applied research (6 to 8 per cent) than bachelors (15 per cent), and, particularly, than holders of advanced degrees (22 to 30 per cent). Some 19 per cent of the Ph.D's and 10 per cent of the master's degree holders were engaged in teaching, while only 1.5 per cent

[34] Or the slight decrease, according to Wolfle (*op. cit.*, pp. 95–96).

[35] Andrew Fraser, *The Engineering Profession in Transition*, Engineers Joint Council, 1947, p. 26.

of the bachelors and 1 per cent of those with some or no college training were so engaged. The proportions engaged in construction supervision were inversely related to education level. Only 1 per cent of the Ph.D's and only 2 per cent of the masters were performing this function, while 4 per cent of the bachelors, and 6 per cent of those with less than full college training were engaged in this activity.

Thus for those functions in which about two-thirds of the society members were engaged, nongraduates were somewhat more concentrated in technical management and construction supervision than graduates and somewhat less concentrated in development and applied research (particularly in relation to holders of advanced degrees). Both nongraduates and bachelor's degree holders had much smaller proportions in teaching than did advance degree holders and somewhat larger proportions in design.[36]

The remaining society members were scattered over more than twenty functions and only in maintenance and operation (in which nongraduates were more concentrated than bachelor's degree holders and, particularly, advanced degree holders) and in basic research (in which the reverse was true) were there marked differences in education levels.

It would appear, then, that nongraduates engage in activities that are essentially similar to those of graduate engineers, particularly those of engineers with four years of college training who comprise the bulk of the college-trained profession. But nongraduates are more likely to be found in administrative or operational positions and less likely in research or teaching positions.

[36] A similar pattern is found in the distributions of a broader sample of engineers, i.e. not restricted to society members (*Employment Outlook for Engineers*, pp. 99–100).