Future Demand for Transportation Professionals: The Outlook for Engineers in State Departments of Transportation

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A generational shift is occurring in transportation agencies. Thousands of transportation professionals that were hired by federal, state, and local governments during the period of growth and prosperity following World War II are about to retire. The agencies that these professionals are leaving have hired relatively few new professionals during the last decade, as public programs have contracted or remained constant. A new generation of transportation professionals will soon be taking charge.

In state departments of transportation and county highway agencies, the dimensions of this turnover are exceptional. One-third of their engineers will retire during the coming decade. These organizations need to take special steps to recruit and train the needed talent.

But replacing the skills lost through retirement is only part of the solution. Some new skills will be needed as agencies adjust to future program priorities, future public expectations, and future technological capability. There will be new resources to meet the challenge as professionals from varied disciplines apply their skills to transportation, and as increasing numbers of women and minorities enter professional transportation fields. Public agencies now face a unique opportunity to reshape their organizations to do tomorrow's job, for tomorrow's citizens, using tomorrow's tools. Together with the nation's universities these agencies face a unique challenge to put in place the education and training that will equip tomorrow's professionals to deal with this challenge.

In response to a mandate included in the Surface Transportation Assistance Act of 1982, the Transportation Research Board assembled a committee, chaired by Lester A. Hoel, Hamilton Professor and Chairman, Department of Civil Engineering, University of Virginia, to examine future transportation professional needs at all levels of government. This paper contains information drawn from one part of the preliminary report of that committee, namely the outlook for entry-level engineers for state departments of transportation.

Among the many disciplines that contribute to state departments of transportation, engineers are a key group because nearly three-fourths of the 41,000 professionals now employed by state departments of transportation are civil engineers. Although future programs and public expectations of those programs will reshape the types of professional skills required, engineering programs will continue to supply a substantial portion of the professional staff within state departments of transportation. The number of state transportation professionals grew during the 1950s and 1960s as the nation's highway program grew, and it declined during the 1970s as the highway program stabilized and declined, in terms of constant dollars. With the passage of the Surface Transportation Assistance Act of 1982 and with increases in state-financed programs, the highway program started to grow again in the early 1980s.

With the network of roads and transit links largely in place, maintenance and rehabilitation of the existing highway and transit system will continue to be an abiding concern. Maintenance of roads, bridges, trackbed, buses, and other rolling stock will be essential to make the most efficient use of the nation's enormous investment in its transportation system. Some capacity expansion, however, will be necessary because of the inexorable growth of traffic in specific localities.

Continued attention will also be given to costs, not just monetary costs, but the broader costs implicit in natural resources and people. Budgetary pressures will continue to force fiscal constraint and conservation. Efficient use of existing facilities and services will continue to compete with capacity expansion as potentially cost-effective ways to meet the public's growing demand for transportation. Transportation professionals will become increasingly vigilant of ways to save the taxpayers' dollars and to spend money as wisely as possible. Those professionals will also continue to be held responsible for the environmental and safety implications of their actions.

During the next 15 years, the structure of the nation's chief transportation institutions probably will remain the same. The existing federal agencies, state governments, cities and counties, as well as regional agencies and special districts will continue to share the responsibilities for the improvement and care of transportation facilities.

The technology supporting this industry will benefit from the advantages offered by faster, smaller, and less expensive computers. Some manifestations of the work station of the future appear in some offices today--computer terminals near every desk, electronic mail, easy access to huge data bases, electronic word processors, decision-making tools such as simulation models and spreadsheets, and electronic engineering aids such as computer-aided design and drafting. Rapid change in engineering and office automation, as well as in field applications of computers, is expected. Construction and maintenance management systems for highway engineers will become more sophisticated and effective. Portable computers and telecommunications already available may allow engineers in the field to find better solutions to their problems with less paperwork.

The human resources that will be available to address transportation needs will also be evolving. Many transportation functions, particularly in state departments of transportation, have traditionally been performed by civil engineers. In many instances, rigid certification procedures have been established to ensure technical competency in design and construction projects that involve substantial public safety concerns and large expenditures of taxpayers' funds. Such procedures have also helped to insulate professional staffs from political patronage and to ensure that they work in the avowed public interest. Certainly, strong technical capability is crucial to success. For example, there is evidence that links the recent strong economic performance of Japanese industry compared with that in the United States to the relatively large fraction of engineers among production workers in Japan. Similarly, the construction of the Interstate highway system, which has been a dominant accomplishment of the current generation of state engineers, was done with remarkable efficiency, dedication, and integrity. Nevertheless, the basic skills that underlie these professional accomplishments--analytical ability, knowledge of physical systems and their properties, communications skills, and creativity--are not necessarily closely correlated with current certification procedures. As a result, nonengineering professionals complain of the lack of opportunity in some state departments of transportation, and they question the current relevance of certification procedures that were established in the era when top priority was given to rapid completion of necessary construction.

Provision of necessary skills, rather than disciplinary credentials, is the key concern. The future highway program, in which rehabilitation is as important as new construction and safety and other public concerns are growing in importance, may need a different set of professional qualifications than did past programs. Reflecting this broadening of skill requirements, increasing numbers of state chief administrative officers now come from fields other than engineering. Whether there should be greater diversification in the professional ranks is a complicated question that depends on each agency's civil service laws, agency composition, availability of candidates, and other factors. Nevertheless, now is the time for state departments of transportation to ask the question, in anticipation of high rates of future turnover and the opportunity for redirection that the coming decade will bring.

In the coming decade, slow growth in state highway programs--perhaps 1.8 percent per year--appears likely. Allowing for growth in productivity, this means that professional staffs in state departments of transportation may grow by about 1.1 percent per year. At the same time, high rates of retirement will create serious stress for many state departments, particularly those that did little or no hiring throughout the 1970s. Overall, an average of about 3.1 percent of professionals are projected to retire each year throughout the coming decade. This is far higher than the average of 1.9 percent experienced by civil engineers in general.

Most of the positions vacated by retiring engineers during the next 5 to 10 years will require far more background and experience than can be provided by new entry-level engineers who will soon be starting their careers. Nevertheless, the pending surge in retirements within state departments of transportation will initiate a sequence of promotions and reorganizations which, when traced through the organizational hierarchy, will ultimately lead to an upturn in the number of entry-level engineers that states hire. Ensuring an adequate supply of new graduates is part of any long-term resolution of professional needs.

The output of the nation's educational system is at a turning point, however. In the past 15 years, college enrollments have risen as the baby-boom generation entered college and as the proportion of high school graduates entering college increased. The coming decade will bring a decline in the size of the college-age population, and the fraction of that population entering college will not be growing. The result is that the number of college enrollments will decline in the years ahead. Further, the share of these graduates that enter civil engineering may continue to decline. Although this share has declined throughout the last decade, the effect was not obvious in the job market because baby-boom-driven increases in the total number of graduates more than offset the ever smaller share of these graduates studying civil engineering. Thus, the number of civil engineers increased even as the share of engineering students entering civil engineering dwindled. The coming decade begins with both these trends headed downward--both total graduates and the civil engineering share. The result is that the number of civil engineering graduates will decline rapidly, and this could lead to shortages of qualified entry-level engineers several years hence unless recent trends are reversed. In examining whether the future supply of entry-level engineers to state highway agencies will be sufficient, it is helpful to focus separately on five components:

- The outlook for future college enrollments in general, particularly in engineering fields;
- The share of engineering students entering civil engineering;
- The number of new graduates that are United States citizens and able to work in the United States;
- The proportion of these graduates that state highway agencies recruit; and
- How the number of new engineers that states recruit compares with the number of new recruits needed.

Each of these five components is explored in sequence later in this paper. Before turning to future trends, however, the current market for civil engineers is sketched briefly.

CURRENT MARKET FOR CIVIL ENGINEERS

Currently there appears to be an adequate supply of civil engineers available to the states. Various labor market indicators support this conclusion:

- Low job and salary offers to new engineering graduates,
- Small changes over time in the salaries of state highway engineers relative to other types of engineers in positions of comparable responsibility, and
- Few major industrial employers reporting a lack of qualified applicants for civil engineering job vacancies.

The College Placement Council reports the number of job offers to new graduates receiving bachelor's degrees in civil engineering more than doubled from 1977 to 1981 but then plummeted by 80 percent in 1983, probably largely in response to the severe recession in the construction industry (Table 1). In con-

TABLE 1 Number of Job Offers to Recipients of Bachelor's Degrees in Civil Engineering and Electrical Engineering, 1974-1983 (1)

Year	Civil	Electrical[a]
1977	2,178	6,106
1979	4,424	10,742
1981	4,416	10,768
1983	892	8,285

Note: As reported to the College Placement Council.

[a]Including computer sciences.

trast, job offers to electrical engineers have been two to three times the level of offers to civil engineers and declined only 23 percent from 1981 to 1983.

Average monthly starting salaries of new recipients of bachelor's degrees in civil engineering declined in current dollars from $1,925 in July 1982 to $1,869 in July 1983. In real terms, this 1983 salary was lower than for most other engineering disciplines. In addition, the starting salaries of civil engineers with bachelor's degrees had fallen below the 1974 level in real dollars, unlike the starting salaries of electrical, aeronautical, industrial, and mechanical engineers, which had risen (Table 2). The real salaries that state highway engineers receive relative to engineers of all types in the private sector with similar responsibility have also declined from 1975 to 1983 (Table 3).

TABLE 2 Average Starting Salaries of Recipients of Bachelor's Degrees in Various Engineering Curricula, 1975-1983 (1)

Year	Civil	Electrical[a]	Aeronautical	Industrial	Mechanical
1974	2,064	2,105	2,052	2,090	2,137
1983	1,976	2,249	2,118	2,164	2,215

Note: As reported to the College Placement Council (salaries in 1984 dollars).

[a]Including computer science.

TABLE 3 Index of Change in Average Salaries of Selected Classes of State Highway Engineers Relative to Average Salaries of All Types of Engineers with Comparable Responsibility in Private Industry (2-5)

Year	State Highway District Engineer[a]	Private Sector Engineer with Comparable Responsibility[b]	State Highway Project Engineer[a]	Private Sector Engineer with Comparable Responsibility[b]
1975	0.80	1.03	0.59	0.93
1976	0.83	1.03	0.66	0.93
1979	0.76	1.04	0.53	0.92
1983	0.76	1.09	0.55	0.96

[a]Average salaries of district and project engineers obtained by taking the midpoint of the salary range for each state reported in the AASHTO Highway Salary Survey (2) and then calculating the mean over all states.
[b]From AASHTO Transportation Salary Survey (3). Index created by dividing average salaries of types of employees shown in table by average salaries of Attorney IV in the same year. Attorney IV is defined in the AASHTO Transportation Salary Survey (3). This procedure corrects for changes in cost of living.

All of these salary trends suggest that the market for civil engineers has been soft for a decade, and there has been a more than ample supply of civil engineers in the last 2 years.

Only a small percentage of major industrial employers of engineers reported to the National Science Foundation that there have been insufficient qualified applicants to fill vacant civil engineering positions. The percentage of employers reporting such difficulties dropped from 12 percent in 1981 to 3 percent in 1984 (Table 4). The corresponding percentages were substantially higher in many other fields, suggesting that the supply of qualified civil engineers was greater, compared to the demand, than was the case in many other fields. The current salary structure in civil engineering may change in future years as the excess supply of highway professionals evaporates.

Currently, salaries (midpoint of the salary range) for highway professionals, such as district highway engineers, are significantly lower in the southeastern part of the United States compared to other portions of the country (Table 5). There appears to be no significant difference among salaries of highway engineers in other portions of the country.

TABLE 4 Percent of Private Sector Firms Reporting Insufficient Qualified Applicants for Various Engineering Positions

	Type of Engineering			
Year	Civil	Electronic	Computer	Petroleum
1981	12	58	51	65
1982	4	32	21	19
1983	5	7	6	7
1984	3	12	15	4

Source: National Science Foundation.

Such comparisons do not reflect variations in employee benefits, differences in regional cost of living, or differences in working conditions. Currently, state employee benefits in transportation agencies range from 16 to 59 percent of employee salaries, the mean being 36.5 percent (Table 6).

A 1983 salary survey of the Institute of Transportation Engineers (ITE) indicates that the mean salary of ITE members in state government, $35,140, is among the lowest in the civil engineering industry, nearly $8,000 below the mean level the federal government pays, and more than $5,000 below the amount consultants receive in private practice (Table 7). Members of ITE in public transit and academia also receive higher salaries than those in the states. These salary levels have not been adjusted to account for the length of experience of employers, which normally explains a large portion in the variation from one employer to another.

OUTLOOK FOR COLLEGE ENROLLMENTS

Since 1960 the most important demographic trend affecting college enrollments has been the dynamics of the baby boom. Beginning around the mid-1960s, the large group born immediately after World War II began entering college, and for about 10 years, college enrollments rose rapidly. A further stimulus to the growth in college students was the increase in the number of women and minorities entering higher education. From 1960 through 1975 total college enrollment of persons in the 18 to 24 age bracket rose from 2.2 million to 6.9 million. Female enrollments

TABLE 5 Salary Ranges of Key Professional Positions in State Departments of Transportation and Highway Organizations, 1983-84 (4)

State	District Engineer	Project Engineer	Graduate Civil Engineer (BSCE)	Journey Level Transportation Planner
Alabama	33,826-51,610	19,739-29,900	21,772-33,020	25,168-38,324
Alaska	N/A	38,124-45,192	26,892-32,040	43,560-51,588
Arizona	34,352-46,637	29,516-35,528	20,970-24,713	22,038-28,975
Arkansas	40,760	28,808-37,622	16,328-23,348	27,560-36,400
California	34,548-52,980	30,756-37,116	19,812-22,764	24,876-30,012
Colorado	39,576-50,508	25,512-32,556	21,576-24,972	34,188-43,632
Connecticut	34,475-42,320	24,911-30,328	20,382-22,968	24,911-30,328
Delaware	26,669-44,604	23,325-36,977	15,382-25,057	24,946-40,688
District of Columbia	51,058-63,700	43,410-56,424	14,054-18,284	14,054-18,284
Florida	37,000-67,500	20,859-28,417	16,307-21,882	N/A
Georgia	27,996-43,004	18,390-27,996	19,152-25,722	18,390-27,996
Hawaii	30,228-48,156	23,844-36,000	16,116-23,844	21,768-32,820
Idaho	32,801-48,484	23,296-34,444	17,388-25,688	19,117-28,329
Illinois	31,620-46,800	25,200-36,900	19,800-25,800	21,000-30,780
Indiana	26,546-41,340	21,112-31,070	19,500-28,860	17,342-25,636
Iowa	30,909-41,704	24,484-32,716	18,907-24,690	17,909-21,965
Kansas	32,256-44,736	22,656-31,308	19,092-26,436	17,484-23,676
Kentucky	29,856-47,808	22,272-35,688	15,072-24,144	16,608-26,592
Louisiana	34,308-49,740	24,336-36,036	21,216-30,756	26,052-37,608
Maine	24,024-33,530	20,584-27,976	16,058-21,902	17,638-24,086
Maryland	31,132-44,165	21,237-27,894	16,995-22,316	21,237-27,894
Massachusetts	34,528-43,086	22,495-27,799	18,646-22,742	30,194-37,557
Michigan	36,561-49,026	39,609-52,993	19,585-24,764	22,446-30,380
Minnesota	36,310-48,170	26,956-35,934	21,151-26,016	19,606-25,766
Mississippi	31,223-46,572	22,019-32,976	17,427-26,089	17,427-26,089
Missouri	38,200-48,000	21,948-30,384	19,200-22,056	21,948-30,384
Montana	32,212-41,316	20,785-28,311	16,159-22,093	17,475-23,861
Nebraska	30,219-42,307	22,629-31,681	19,126-25,501	16,944-23,722
Nevada	30,951-42,547	23,751-32,367	20,888-24,805	20,021-27,090
New Hampshire	24,005-29,660	21,333-26,150	14,567-17,628	17,004-20,495
New Jersey	36,177-48,833	26,995-36,446	19,139-20,010	23,318-31,483
New Mexico	32,184-45,300	26,472-43,140	17,916-29,196	17,064-27,804
New York	57,718-68,172	30,326-41,403	18,718-22,338	28,772-33,740
North Carolina	28,560-43,836	21,468-32,856	19,212-20,088	17,928-27,216
North Dakota	28,956-42,420	21,600-31,644	16,128-23,628	16,932-24,804
Ohio	29,099-41,350	19,781-27,622	17,992-23,941	16,557-21,778
Oklahoma	39,271-52,626	23,383-38,313	18,429-24,697	23,521-31,520
Oregon	34,044-43,428	25,368-32,376	18,084-23,100	N/A
Pennsylvania	37,653-48,098	21,379-29,066	17,976-23,276	21,379-29,066
Puerto Rico	17,220-21,720	13,260-16,860	11,280-14,280	10,380-13,080
Rhode Island	N/A	20,883-23,577	18,681-21,733	23,429-26,531
South Carolina	27,191-38,540	19,867-28,159	16,982-24,071	18,368-26,036
South Dakota	35,500	20,134-31,325	17,014-26,104	15,662-23,837
Tennessee	22,200-29,052	18,840-25,188	16,404-22,200	14,592-20,172
Texas	50,000-52,700	31,968-40,272	23,784-29,952	25,392-31,968
Utah	34,076-49,778	24,868-36,269	19,773-26,058	17,811-26,058
Vermont	21,299-40,477	16,973-32,032	13,562-25,189	16,973-32,032
Virginia	28,397-38,781	15,213-20,791	18,183-20,791	19,884-27,150
Washington	43,740-55,992	26,700-34,176	17,988-23,016	17,988-23,016
West Virginia	28,464-50,988	22,284-38,316	16,884-28,872	14,724-25,080
Wisconsin	38,275-53,198	24,785-32,675	20,664-25,478	24,883-34,584
Wyoming	37,968-58,908	29,640-45,984	19,968-30,984	19,475-30,240

TABLE 6 Employee Benefits as a Percent of Average Salaries of State Highway Agencies

State	Benefits Expressed as a Percentage of Average Salary	State	Benefits Expressed as a Percentage of Average Salary
Hawaii	59	Nevada	35
New York	55	Tennessee	33
Missouri	54	West Virginia	33
Maryland	52	Arkansas	32
Florida	50	Delaware	32
Iowa	50	Minnesota	32
Ohio	49	California	31
Alabama	48	New Jersey	30
Mississippi	46	Washington	30
Oregon	46	Rhode Island	29
Louisiana	45	Virginia	29
North Carolina	44	Wisconsin	29
Colorado	43	Vermont	28
Oklahoma	43	North Dakota	25
Idaho	42	Massachusetts	24
Texas	41	New Hampshire	20
Utah	41	New Mexico	20
Kentucky	40	Montana	18
Nebraska	39	South Carolina	17
Illinois	38	South Dakota	16
Kansas	37	Alaska	n.a.
Wyoming	36	Arizona	n.a.
Connecticut	35	Georgia	n.a.
Maine	35	Indiana	n.a.
Michigan	35	Pennsylvania	n.a.

Note: n.a. = not available.

Source: American Association of State Highway and Transportation Officials survey of state departments of transportation and highway agencies for the Transportation Professional Needs Study, Supplement, 1984.

increased from 0.8 million to 2.8 million, and black enrollments increased from 134,000 to 665,000. Meanwhile, the United States population was growing from 179.3 million to 214.9 million (7).

After 1975 the 18 to 24 age group both in and out of college stabilized at around 30 million and has remained at that level from 1979 through 1982. Meanwhile, the high school population has been declining, portending a drop in college enrollments in the last half of the 1980s (7).

Since 1960 the total number of engineering degrees has fluctuated, but the long-term underlying trend has been one of growth (8) (Figure 1). Various economic forces and government actions have spurred this growth. For example, the federal government increased student financial aid after the Russians launched Sputnik; the space program created a large extra demand for engineers; and rapid growth in the computer and microelectronic industry has greatly increased the

TABLE 7 Mean Salary of Members of the Institute of Transportation Engineers by Type of Employer (6)

Employer Category	Mean Salary ($)
Association	45,577
Manufacturer/supplier	45,429
Other	43,250
Federal government	43,245
Private practice	40,764
Public transit	39,408
Academic	38,024
City/local government	35,627
State/province government	35,140
County government	35,012
Regional transportation	33,363

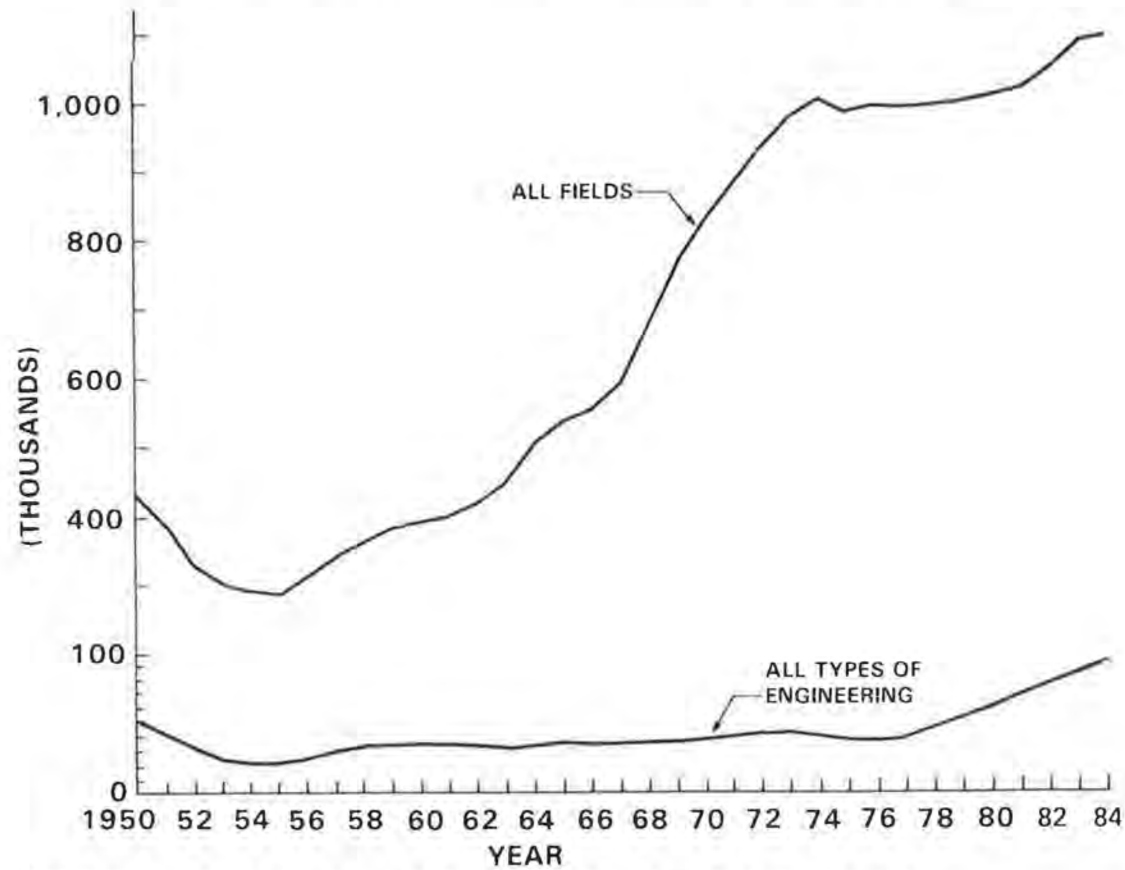

FIGURE 1 Bachelor's and first professional degrees (1).

demand for engineers. From 1970 to 1980 the total number of engineering degrees increased from 42,966 to 58,742, and according to the Engineering Manpower Commission, had reached 72,471 by 1983 (9,10). In the next 2 years declining college enrollments will cause the number of engineering degrees to decline. The number of bachelor's degrees in engineering will decline from 75,999 in 1984 to 71,372 in 1989, and master's degrees will decline from 16,310 to 15,930.

Share of Engineers Entering Civil Engineering

Bachelor's degrees awarded in civil engineering increased from 6,526 in 1971 to 10,524 in 1972. During this same period, master's degrees awarded in civil engineering increased from 2,425 to 2,995 (Table 8). In relative terms the growth in

TABLE 8 Number of Civil, Construction, and Transportation Engineering Degrees

	Bachelor's (4 or 5 years)			Master's			Doctor's Degree		
Year	Total	Men	Women	Total	Men	Women	Total	Men	Women
1981-1982	10,524	9,333	1,191	2,995	2,725	270	329	315	14
1980-1981	10,678	9,557	1,121	2,891	2,684	207	325	316	9
1979-1980	10,326	9,349	977	2,683	2,476	197	270	264	6
1978-1979	9,809	8,865	944	2,646	2,503	143	253	249	4
1977-1978	9,135	8,450	685	2,685	2,553	132	277	271	6
1976-1977	8,227	7,799	429	2,964	2,835	129	309	303	6
1975-1976	7,923	7,657	248	2,999	2,900	99	370	361	9
1974-1975	7,651	7,509	142	2,769	2,695	74	356	347	9
1973-1974	8,017	7,889	127	2,652	2,603	44	368	364	4
1972-1973	7,390	7,318	72	2,627	2,589	38	397	388	9
1971-1972	6,803	6,741	62	2,487	2,449	38	415	413	2
1970-1971	6,526	6,474	52	2,425	2,397	28	446	443	3

Source: National Center for Education Statistics, annual series, 1948-1980.

the number of bachelor's and master's degrees awarded to women in civil engineering was dramatic, an increase of more than 20 fold, but this increase still represents only about 1,000 people. Thus, the fraction of women recipients of bachelor's degrees is still only about 10.3 percent of all students earning bachelor's degrees in this field in 1982, according to the National Center for Education Statistics. The percentage of women receiving bachelor's degrees in civil engineering is less than the percentage of women receiving degrees in all branches of engineering, which in turn is far below the fraction of women earning bachelor's or first professional degrees in business (39 percent), law (52 percent), and veterinary science (46 percent) (Table 9). The number of blacks receiving bachelor's degrees in civil engineering has also greatly increased but is likewise far smaller than the black share of the population.

Although the number of civil engineers has been increasing, this growth makes a strong downward trend in the relative popularity of civil engineering degrees. For almost a decade, a smaller and smaller share of engineering graduates has

TABLE 9 Approximate Percentages of Women Enrolled and Graduating in the Professional Fields, 1984 (11)

Profession	First Year Enrollment	Bachelor's and First Professional Degrees
Business managers	43.7[a]	39.3
Architects	28.4[a]	29.8
Engineers	15.8	13.2
Lawyers	38.4	50.8
Physicians	31.6	26.7
Dentists	24.4	20.6
Optometrists	26.7	22.0
Osteopaths	25.4	19.8
Podiatrists	20.7	10.5
Veterinarians	48.6	46.4
Pharmacists	53.9	49.4

[a]Undergraduate.

selected civil engineering as a specialty. The share of engineering degrees awarded to civil engineers dropped from about 20.3 percent in 1976 to 15.7 percent in 1982 (Figure 2). Similarly, the share of all master's degrees in engineering awarded to civil engineers showed a parallel decline until 1980, but then rose in 1981 and 1982. Some of this upturn in master's degrees may have occurred as students deferred entering a slack labor market and tried to improve their long-term earning potential by seeking an advanced degree.

Enrollment data on the number of students in civil engineering reveal some interesting trends that will also affect future degrees awarded in civil engineering (12). First, in the mid-1970s most students who selected civil engineering as a specialty made the choice in their freshman or sophomore years. At the time, students were undoubtedly responding to the previous growth in civil engineering employment opportunities and expectations of future opportunities. By the 1980s the demand for civil engineers had declined relative to the demand for other types of engineers, particularly electronic engineers, and fewer students elected civil engineering early in their college years. In addition, although many university engineering programs became more specialized, in some programs students were encouraged to avoid specialization until later in their academic program. It is also possible that increasing numbers of students receive general engineering education in 2-year colleges and then specialize when they switch to a 4-year college or university program.

Enrollment data strongly suggest that since 1980 an increasing share of graduates has selected civil engineering at the last moment--in the fourth year of undergraduate work. Each of the lines in Figure 3 shows the size of each graduating class of civil engineers as it progresses through its 4-year curriculum. For example, the class of 1978, shown to the left of the figure, had only about 8,000 members in 1975, the freshman year. But this number grew to about 10,000 in 1976, the sophomore year, and to more than 12,000 by 1978, when the class graduated. By 1978, however, there is virtually no increase in the number of civil engineers between freshman and sophomore years, as is apparent from the flat leftmost portions of the curves for the classes of 1981 through 1985.

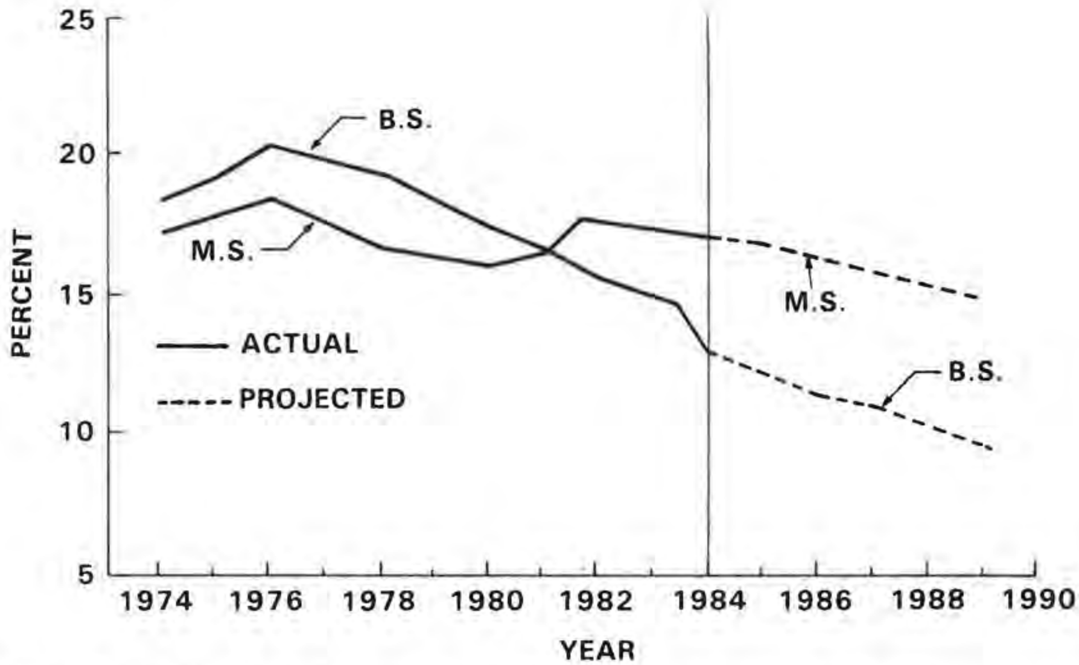

FIGURE 2 Civil Engineering graduates as a percent of all engineering graduates (9-10).

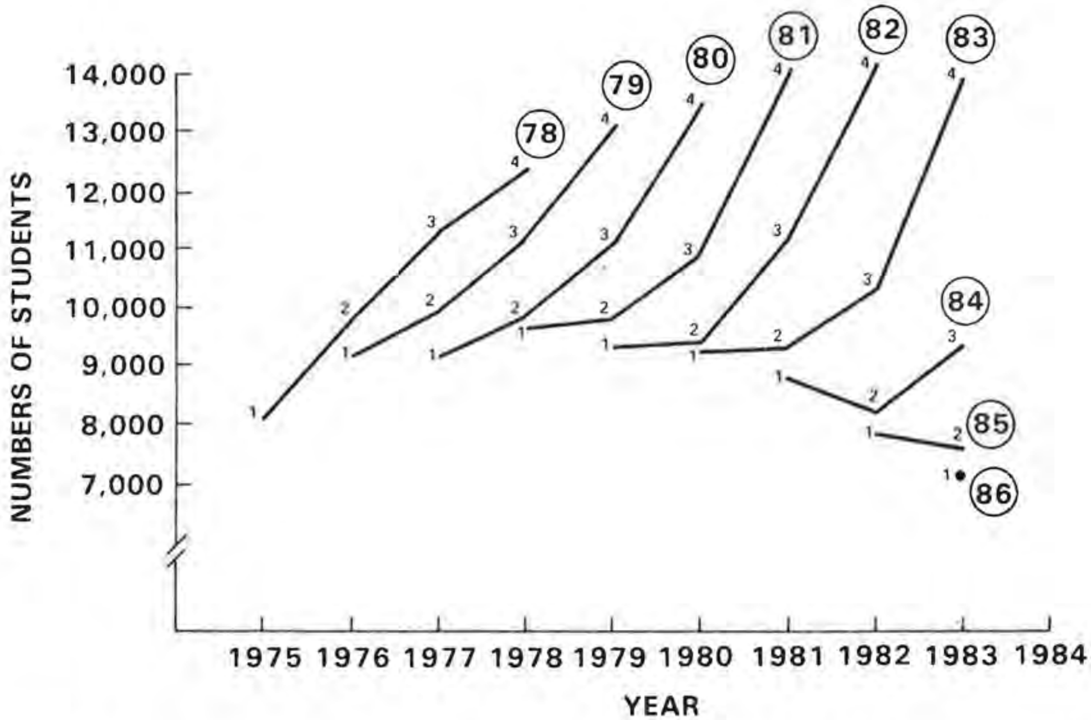

FIGURE 3 Trend in civil engineering enrollments (undergraduates). Note: 1, 2, 3, and 4 representing first-, second-, and fourth-year civil engineering undergraduate enrollments for the class due to graduate in the spring of the circled year.

Indeed, the number of civil engineering enrollments remains relatively static until the senior year, when a substantial number of students select civil engineering. By the time the class of 1983 went to college, the number of students enrolled in civil engineering in their junior year was only about 1,000 more than the number enrolled as freshmen. The only sizable increase occurred in the final year, when nearly 4,000 students enrolled in civil engineering in their senior year.

To some degree, this shift in the dynamics of civil engineering enrollments within the 4-year curriculum may be due to the inability of some students to complete engineering degrees in other fields because of overcrowded courses or to compete against the better students who selected fields of study in computers, genetic engineering, robotics, or other fields that receive extensive publicity and that attract many of the best students. Those students that choose to remain within a general engineering curriculum instead of specializing may account for part of the change in enrollment patterns, and so may the increasing number of students taking their early general engineering courses in 2-year colleges.

The tendency toward late selection of civil engineering as a major suggests that civil engineering may be a second choice for some students. To the extent that this is true, then the civil engineering share could erode still further even as popular competing courses become less crowded as college enrollments fall. Nevertheless, it is assumed here that the share of students enrolled in civil engineering fields continues to taper off according to the historic pattern, and no faster, as shown in Figure 2.

U.S. Citizens

A large proportion of civil engineering graduates are foreign citizens who are legally unable to accept jobs in the United States upon graduation. Eight percent of bachelor's degree recipients, and 26 percent of master's degree recipients were foreign nationals in 1979, according to an unpublished report to the National Science Foundation titled "Projections of Supply Scientists and Engineers to Meet Defense and Non-Defense Requirements, 1981-1984." This means that about 1,500 civil engineering graduates out of the national total of about 13,500 must return to their native countries and are not eligible to work in the United States upon graduation. Many of these graduates do eventually reenter the United States labor market, however. Immigration of civil engineers to the United States in 1984 has been estimated to be about 750 per year, equivalent to roughly one-half the number of foreign students graduating in civil engineering each year (13).

The high proportion of foreign nationals has also been a source of concern to educational institutions as they plan to meet their professional needs. The low number of United States citizens choosing to earn doctorates has been identified as a key problem that educational institutions now face. Colleges and universities are concerned that they have adequate faculty resources to continue their programs during the coming decade (13).

SHARE RECRUITED BY STATE HIGHWAY AGENCIES

Although the vast majority of professionals within state highway agencies are civil engineers, they comprise only a small part of the nation's trained civil engineers. To be counted among the civil engineers working in state departments of transportation, three conditions must be met. The engineer must be employed, must be practicing civil engineering, and must be employed by a state agency. First, between 7 and 9 percent of civil engineers do not enter the labor force, either because they go on to graduate school, because they are unable to find jobs, or because of some other reason (14).

Second, of those taking jobs, only about 80 percent or more will work in areas of civil engineering (15). Some shifting in and out of fields is expected because individuals have unique opportunities, including jobs in family businesses, in firms experiencing local shortages, or in other fields. Nevertheless, market forces heavily influence these patterns. Fields experiencing shortages of qualified professionals, such as computer science, draw candidates from other areas. Fields with a surplus of trained professionals lose some of their graduates to jobs in areas where job openings are more abundant. A net loss of trained civil engineers to other fields thus probably partly reflects a slack market for civil engineers.

Third, allowing that some civil engineering graduates do not take jobs at all, or take them in areas other than civil engineering, it is important to recognize that only 17 percent of the nation's civil engineers work in state highway agencies. Most of the 10,000 new civil engineers graduating each year take jobs in industry, consulting, local government, state government, and various other sectors (16). Assuming that this trend continues in future years, state highway agencies will need to recruit a corresponding percentage of new civil engineering graduates. Variations from this percentage will arise due to the large number of retirements expected within state departments of transportation, the more rapid growth of jobs for civil engineers in other organizations, and various other factors. Nevertheless, to make trends in academic enrollments comparable to trends in state professional needs, a useful benchmark is to assume that states continue to attract 17 percent of all civil engineering graduates, and then to assess the implications of the resulting figures. This exercise shows that, although there will be more candidates than jobs for the next 2 years, this situation will be reversed beginning in 1986. Thus the job market for entry-level engineers for state highway agencies promises to tighten up, as discussed next.

FUTURE AGENCY NEEDS COMPARED WITH FUTURE SUPPLY OF GRADUATES

Based on the preceding discussion, the following assumptions appear to offer a reasonable basis for projecting the future supply of graduating civil engineers available to state departments of transportation:

- The number of graduates in all fields of engineering will decline from 75,999 in 1984 to 71,372 in 1989 because of the declining college-age population, as forecast by the Scientific Manpower Commission (9);
- The share of these graduates entering civil engineering will continue to decline by about five percentage points per year (17) (American Society of Civil Engineers Enrollment Information, Fall, 1983);
- About 8 percent of recipients of bachelor of science degrees in civil engineering and about 26 percent of recipients of master of science degrees will be foreign nationals who must leave the United States upon graduation (16);
- Between 750 and 800 foreign nationals with degrees in civil engineering will immigrate to the United States each year (13);

• Between 7 to 9 percent of civil engineering graduates will not enter the labor force (16);

• About 20 percent of graduating civil engineers will be employed in fields other than civil engineering (15); and

• About 17 percent of all civil engineers entering the labor force will be hired by state departments of transportation.

Each of these factors is uncertain and subject to fluctuation, but before discussing some of the adjustments that might occur, and indeed probably would occur, it is instructive to examine the implications of the foregoing trends if they continue unchanged. Together, these assumptions imply that state departments of transportation sought about 1,450 new entry-level civil engineers in 1984, and that the states' pro-rata share of civil engineering graduates number about 1,630 in 1984 (Table 10). In 1985 state requirements will increase slightly to about

TABLE 10 Supply of New Civil Engineering Graduates and Other New Entrants to State Highway Organizations and Comparison with Requirements

	Supply		Requirements				Future Labor Market Conditions		
Year	Total Addition to Supply in U.S.	Number Supplied to State Highway Agencies	Total Engineers	Net Growth (Allowing for Productivity Improvements)	Attrition (Retirements and Deaths)	Total Requirements	Change in Supply	Change in Demand	Surplus/ Shortage
1984	9,440	1,630	29,969	529	916	1,450	1,630	1,450	+180
1985	8,990	1,550	30,508	539	933	1,470	1,550	1,470	+80
1986	8,500	1,460	31,057	549	949	1,500	1,460	1,500	-40
1987	8,000	1,380	31,616	559	966	1,530	1,380	1,530	-150
1988	7,590	1,310	32,185	569	984	1,550	1,310	1,550	-240
1989	7,210	1,240	32,764	579	1,002	1,580	1,240	1,580	-340

1,470 entry-level engineers, and the state share of national graduates available to take jobs will still be somewhat larger. In 1986 through 1989, however, the number of engineers projected to be needed by the states is beneath their pro-rata share of engineering graduates. Then, if the trends assumed earlier do not change, the states could find that they are unable to hire sufficient numbers of new graduates. This does not suggest that a shortage is likely, however. Rather, it suggests that some of the trends will shift in response to state needs. For example:

• The share of practicing civil engineers state highway agencies attract could increase above their historic, pro-rata share. As turnover in state agencies creates new openings and enhances the advancement potential for entering employees, more new employees may be attracted to state agencies. As long as other prospective employers of civil engineers are not experiencing shortages, probably state agencies could succeed in bidding for a larger share of new graduates. However, using assumptions similar to those preceding--especially the declining fraction of engineering students selecting civil engineering--it appears that the market for civil engineers of all types will be much tighter by the end of the decade (Figure 4). The accuracy of any such forecast is too poor to permit much confidence in forecasts for individual years. Even so the ability of the states to attract a disproportionate share of new civil engineering graduates would probably be short lived.

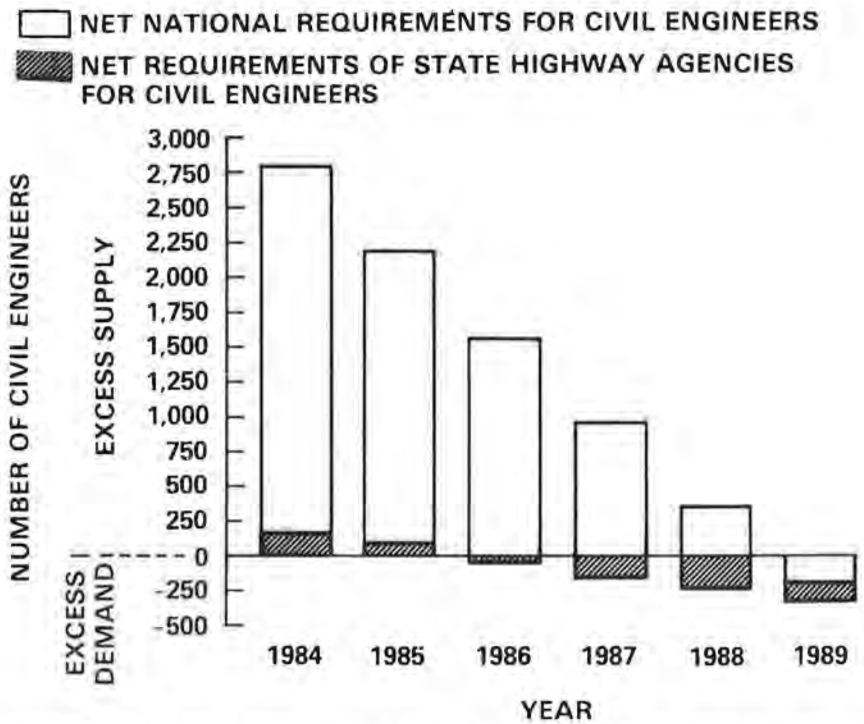

FIGURE 4 The net requirements for the nation's civil engineers and for civil engineers entering state transportation organizations, 1984-1989.

• The decline in the share of engineering students attracted to civil engineering could abate or halt as job opportunities improve; the share could even increase. This adjustment would probably take several years. Some time would elapse before students recognize better job opportunities and make curriculum choices based on new expectations. The lagged response of students' curriculum choices to future job opportunities might not be as large if the states take special steps now to increase student awareness of future potential. For example, expanded recruitment efforts, greater distribution of material on summer jobs, and cooperative working arrangements for students could help stimulate more student interest in civil engineering. Similarly, there may be ways to cooperate with professional societies to enhance their dissemination of job information.

• The portion of trained civil engineers that take jobs in other fields will probably decrease as job opportunities in civil engineering increase. As the labor market adjusts to improved job opportunities within civil engineering, the new equilibrium that emerges will probably be characterized by a smaller outflow of trained civil engineers into these fields.

• Business schools are now graduating close to 2,000 students per year who have earned transportation and public utility degrees (Table 11). Although most of these business students enter the private sector, they represent an additional source of skills state agencies can draw upon. As the labor market for civil engineers tightens, states may find it not only necessary but desirable to draw increasingly on graduates of transportation-related programs such as business, operations research, geography, and economics. Such graduates have learned skills particularly applicable to planning and investment analysis. With the continuing shift toward maintaining and optimizing the use of existing facilities, these skills will, in many instances, be as useful as traditional civil engineering skills.

TABLE 11 Number of Transportation and Public Utility Degrees

	Bachelor's (4 or 5 years)			Master's			Doctor's Degree		
Year	Total	Men	Women	Total	Men	Women	Total	Men	Women
1981-1982	1,816	1,431	385	129	116	13	2	1	1
1980-1981	1,538	1,275	263	120	111	9	3	3	-
1979-1980	1,322	1,067	255	142	121	21	4	4	-
1978-1979	1,151	940	211	134	130	4	3	2	1
1977-1978	1,084	932	152	158	151	7	1	1	-
1976-1977	1,124	979	145	125	115	10	6	5	1
1975-1976	1,057	958	99	108	103	5	3	3	-
1974-1975	812	747	65	117	116	1	2	2	-
1973-1974	618	588	30	109	109	-	2	2	-
1972-1973	567	548	19	159	157	2	9	8	1
1971-1972	644	641	8	66	66	-	6	6	-
1970-1971	662	656	6	63	63	-	3	3	-

Source: National Center for Education Statistics, annual series, 1948-1980.

Because of the likelihood of adjustments such as these, the projections in Table 10 are not interpretable as evidence of a pending shortage. Rather, they indicate that the surplus of civil engineers, which has been characteristic of recent years, is ending. A recent National Science Foundation study of science and engineering needs for the defense and civilian economy concluded that there would be sufficient civil engineers to meet the nation's growth in requirements through 1987. But the study noted that economic efficiency and labor market performance are not necessarily maximized when supply and demand are in balance. Unless requirements are met with "experienced and appropriately trained" personnel, the quality of the work force will diminish (13).

In a report of the National Research Council's Committee on the Education and Utilization of the engineer it was observed that civil engineers have been in oversupply due to the impact of the recent recession on the construction industry and a reduced demand for environmentally related work. The committee then cautioned that neither shortage nor surplus conditions are static (14). A joint study of the Bureau of Labor Statistics and the National Science Foundation, prepared in 1980, indicated that there would be an adequate supply of most types of engineers in 1990, including civil engineers, provided there was not a sharp increase in the defense budget (17).

CONCLUSION

If current trends in college civil engineering enrollments continue, the number of entry-level professionals needed by state departments of transportation will exceed their historical share of civil engineering graduates beginning around 1987. This means that state departments of transportation, to meet future professional staff requirements, will need to stimulate more enrollments in civil engineering programs, attract a greater share of civil engineering graduates, relax their certification procedures so that professionals from other fields can contribute more easily to their programs, or otherwise restructure their recruitment, training, and compensation policies to ensure that the necessary skills are available. Five steps appear particularly promising in meeting future needs:

- Revamping programs to train mid-level and management engineers to assume the varied responsibilities of retiring professionals (this may require revision of other procedures, such as relocation assistance, to facilitate the accelerated development of in-house professionals);
- Shifting the mix of professional specialties hired. Future program needs and public expectations require greater expertise in nonengineering fields, and the coming decade offers an opportunity to broaden the professional ranks to meet these challenges;
- Using consultants to meet selected skill requirements, such as for specialized engineering skills that are required only occasionally and for which full-time permanent professional staffs may not be the most efficient source;
- Making greater use of technicians, particularly as advances in data processing and other technological improvements create more routine solutions to some of the problems that now require senior engineering judgment; and
- Exploiting the potential of computers through greater reliance on computer-aided design and drafting, automated pavement and maintenance management systems, and other applications.

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