

A Study of the Factors Influencing Attraction and Retention of Engineering Talent With the Ohio Department of Highways

EMMETT H. KARRER, Transportation Research Center, Ohio State University

This report on factors affecting attraction and retention of engineering talent in Ohio and throughout the nation concludes that loss of engineering talent is a serious problem that will probably become more severe. More than 55 percent of the engineers left the Ohio Department of Highways within 3 years, and it is worth noting that low salaries ranked only third among the 5 major causes. Specific suggestions are offered on recruiting, training, and ensuring retention of engineers.

•ALTHOUGH THIS STUDY was initiated by the Ohio Department of Highways, it quickly became apparent that the problem of attracting and retaining engineers in the employment of the state highway department was not unique to Ohio but was a serious problem in many states. Consequently the base of the study was broadened to include information from all state highway departments.

For many years the Ohio Department of Highways has been concerned about the quality and effectiveness of its engineering organization. An engineer-in-training program was initiated in Ohio in 1949, and this program was continued for a period of 10 years. In 1966 an EIT program was re-established in Ohio. As the present version of the training program had not been in force for any appreciable period of time prior to the start of this study in 1967, it was considered by the researchers to be unfair to attempt to critically evaluate that program as part of our study. On the basis of the nearly 100 engineers in training involved in Ohio's EIT program in June 1970 as well as the 70 men who have completed the program and are on permanent assignments within the department, it is proving to be successful.

Reference is also made in this report to the need for construction manuals. Although some manuals have been available for many years within the Ohio Department of Highways, beginning in 1967 they were increased in scope and rewritten in layman's terms, thereby increasing their effectiveness.

MAGNITUDE OF THE PROBLEM

The problem of shortage of engineers and engineering technicians in state highway departments is not new. Shortly after World War II, with the surge of roadbuilding needed to catch up with repair and reconstruction of roads that had been neglected during the war years, the shortage of engineering personnel was very much in the news.

With the initiation of the Interstate Highway Program in 1956, the amount of highway construction throughout the nation increased tenfold, creating a new wave of shortages of engineers. In the past decade this shortage has not been resolved and, if anything, has grown worse. State highway departments not only have failed to attract as many new college graduate engineers as they would like, but they have been losing many competent and experienced engineers.

The seriousness of the situation is reflected in the following summary of the figures furnished by all of the states and the U. S. Bureau of Public Roads as part of our study.

<u>Item</u>	<u>All States</u>	<u>Ohio</u>
Total full-time engineers employed during fiscal year 1968	27,273	680
Number of engineers newly employed during 1968	1,845	39
Total full-time engineering technicians employed during 1968	59,907	3,056
Number of additional engineers immediately desired	3,437	200
Engineers leaving for reasons of retirement or death during 1968	755	26
Engineers leaving for reasons other than retirement or death	1,525	31
Engineers eligible to retire from highway departments within the next 5 years	2,985	200
Number of additional engineers needed by highway departments within the next 5 years	8,431	
Number of additional engineers wanted by contractors within the next 5 years	23,300	
Number of additional engineers needed by cities, counties, federal government, and other industries within the next 5 years	?	

The number of degrees in civil engineering granted by all U. S. colleges in 1968 was 5,446 bachelor's degrees, 2,206 master's degrees, and 416 PhD degrees.

THE CHANGING RESPONSIBILITIES OF THE HIGHWAY ENGINEER

Part of the problem of retention of engineers in highway departments is the rapidly changing picture of the responsibilities of highway engineers. The continuously increasing capacity and complexity of construction equipment, with a resulting increased speed of construction, are placing ever-increasing responsibilities on engineers engaged in construction administration for speedy and correct decisions. The greatly increased volume of highway work combined with the shortage of engineers in the employment of the highway departments is also causing many highway departments to change from the practice of doing all of their own planning, design, and construction engineering to the practice of employing consulting engineers for design and of requiring contractors to do their own construction control. These practices do not decrease the total number of engineers needed by the highway industry; they only shift the responsibilities. If anything, they increase the technical competence needed by state highway engineers.

THE STUDY

The decision that an engineer makes in accepting employment with any organization or his decision whether or not to remain in the employment of that organization is based on opinions. Hence, our study of factors affecting these decisions was in the nature of identifying and evaluating the elements on which these opinions are based.

Our approach to this study of factors affecting the opinions of engineers was first to interview some 20 young engineers who had left the Ohio Department of Highways within the past few years and who were now in positions of responsibility, thus indicating that they were qualified engineers. The opinions expressed by these engineers were summarized and organized into a questionnaire that was then sent to some 300 engineers who had left the Ohio Department of Highways within the past 10 years. In an attempt to make sure that we would detect any peculiarities in the Ohio situation relative to the

retention of engineers, similar questionnaires were sent to some 300 engineers who had left 4 other state highway departments in the same period. The group, including Illinois, Indiana, Kentucky, and Minnesota, is identified as our control group. The many reasons given by engineers for leaving highway departments are summarized and evaluated, and recommendations are made on steps that could be taken to alleviate the situations that had caused these decisions.

A second major phase of the study was to look into the factors affecting the attraction of newly graduated civil engineers to the department of highways. Here again, through questionnaire and interview, all seniors in civil engineering in the 10 schools in Ohio offering a bachelors degree in civil engineering were questioned and stated opinions summarized. A disturbing factor learned through these questionnaires was the very low percentage of civil engineering graduates who indicated that they had received encouragement from their university faculties to accept employment with the department of highways.

The more important observations made from the information gathered and the conclusions reached therefrom are given in the remainder of this paper. The organization is similar to that of the full report of the study where supporting information is given for the statements made here.

RETENTION OF COMPETENT ENGINEERS IN STATE HIGHWAY DEPARTMENTS

1. Cost of losing engineers. Loss of professional engineers after several years of employment in any organization is costly to the organization. Costs can be measured in terms of loss of efficiency in production until new men are trained to replace those who left, loss of the invested time and money for training the engineer who left, and cost of training the new replacement.
2. Length of service. Our study shows that of the engineers who left the Ohio Department of Highways, 17 percent left within 1 year and 55 percent left within 3 years of their starting employment.
3. Value of summer employment during college in motivating engineers to remain with state highway departments. Of the engineers who left the Ohio Department of Highways during the 10-year study period, 41 percent had not been employed by the department during summer vacations before graduation from college. Summer employment of engineering students can be used to motivate interest in the highway industry as a career. It is essential, however, that the engineering students be employed in engineering work and that this work be challenging. It is apparent that unless the supervision of engineering students who are employed for summer work is good, the results may be negative motivation.
4. Engineering graduates from outside of Ohio. Of the engineers who left the Ohio Department of Highways during the study period, 38 percent were graduates from colleges outside of Ohio. It is probable that many young engineers take a job only to get a few years of experience, with the full intention of then leaving that job to return to their home state for permanent professional careers. This is especially true if these young engineers have strong family ties that are an inducement to return to their original homes.
5. Intent of engineers to stay with the state highway department. Eighty-one percent of the engineers who left the Ohio Department of Highways and 76 percent of those from the control group (Illinois, Indiana, Kentucky, and Minnesota) indicated that when they first accepted employment with the state highway department, they fully intended or at least they had open minds regarding the decision, to make such employment a career.
6. Reasons for accepting first employment with the Ohio department of highways. In answer to the question as to what most influenced them to first accept employment with the Ohio Department of Highways, the engineers most often listed the following: (a) engineer-in-training program sounded good, (b) interesting and challenging work, (c) best job available in location where I wanted to work, and (d) opportunity for engineering experience.
7. Misgivings about accepting employment with state highway department. In answer to the question as to what misgivings, if any, they had concerning acceptance of their

first employment with a department of highways, engineers both in Ohio and in the control group, listed the following most often: (a) appeared that politics might influence opportunity for advancement and (b) low salary.

8. Engineer-in-training program. Information from engineers who had left the highway departments indicated that only a very few had originally entered employment through a good orientation or engineer-in-training program.

9. Reasons for leaving state highway department. In an effort to determine the relative importance of the many factors that had a bearing on an engineer's decision to leave the employment of state highway departments, we listed a number of obvious reasons. The men were asked to rate these, giving 10 points for the most important reason, 9 for the second most important, and so on to 0 for the several least important reasons. The number of factors listed most often, both in Ohio and in the control group, were respectively as follows: (a) long-range advancement possibilities looked poor, (b) opportunities for advancement too much influenced by politics, (c) salary was too low, (d) type of work was not challenging, and (e) work assignment did not allow opportunity for use of engineering judgment.

ATTRACTING NEW CIVIL ENGINEERING GRADUATES TO THE OHIO DEPARTMENT OF HIGHWAYS

1. Education beyond the bachelor's degree. When interviewed, the majority (48 out of 85) of senior civil engineering students in Ohio colleges indicated that, after receiving their bachelor's degree in civil engineering, they desired to continue their formal education. Twenty-nine indicated that they wanted to take advanced work in civil engineering, 10 in business administration, and 5 in law.

2. Attitude of students toward summer work with the Ohio Department of Highways. In response to the inquiry as to which summer work experience had the most appeal to them, engineering students gave the following answers most frequently: (a) doing challenging work, (b) having opportunity to use engineering knowledge, (c) having responsibility, and (d) gaining practical experience. Of those who had worked at least one summer with the Ohio Department of Highways, 47 percent thought that they were confined to routine jobs that offered little challenge, a minimal chance to demonstrate engineering ability or responsibility, and poor opportunities for gaining worthwhile experience.

3. Recruiting college seniors in civil engineering. Although 58 percent of the college seniors, when filling in our questionnaire in March or April, 1968 indicated that they expected to graduate in June of that year, only 15 percent, at that time, had accepted employment. Only 23 percent said that they had been offered employment by the Ohio Department of Highways.

4. Factors important to a college graduate in selecting first employment. A most important decision in a young man's professional life is the selection of his first job out of college. In our questionnaire, students were asked to list the factors that had most affected their decision. In the order of number of times listed, the most important factors were (a) challenging work, (b) prospective pay increases and promotions (c) opportunity to increase knowledge by experience, (d) starting salary, (e) opportunity to use engineering judgment, and (f) long-range advancement opportunities. It is observed that retirement benefits and probability of military draft deferment due to occupation were well down in the list of factors considered by the students, being respectively No. 14 and No. 16.

5. Formal in-service training programs. Eighty-two percent of the senior civil engineering students indicated that they preferred to start their professional engineering career in a formal in-service training program.

6. Advice from college instructors concerning employment with state highway departments. Only 22 percent of the senior-year students indicated that their college professors had encouraged them toward any interest in employment with the Ohio Department of Highways. Perhaps an important aspect of this attitude is that some college faculty members who teach highway engineering courses admit knowing very little about the Department of Highways.

7. Starting salaries for civil engineers. Although the starting salaries offered by industry (all employers except government agencies) to civil engineers with a bachelor's degree from the Ohio State University has held fairly close to the average starting salaries for all engineers for the past 10 years, the starting salaries offered by the Ohio Department of Highways has lagged considerably behind salaries offered by industry.

8. Starting salaries offered by state highway departments. As of January 1, 1969, the starting salaries offered by all state highway departments for an engineer with a bachelor's degree in civil engineering averaged \$8,312. The reported range was from \$7,272 to \$9,624 (excluding Puerto Rico); Ohio's figure was \$7,904. Ohio, however, reports that a graduate may start at \$8,736 if he has passed the written examination for his EIT certificate.

MANPOWER UTILIZATION IN STATE HIGHWAY DEPARTMENTS

1. Need for adequate manpower planning. The very critical shortage of engineering personnel that the Ohio Department of Highways, as well as many other state highway departments, now faces, reflects the fact that manpower planning has not received the serious consideration that it deserves.

2. Dollar investment in manpower. As a national average, one-fifth of the money spent for highways goes into salaries of employees, including engineers, engineering technicians, administrators, and other related personnel. Good manpower management dictates that every effort must be made to motivate these personnel to the highest possible productivity and to encourage them to remain in the organization.

3. Anticipated retirement of engineers. Figures reported from Ohio indicate that approximately 29 percent of the present engineering staff will be eligible to retire within the next 5 years. In addition, the persons who will leave the service because of disability, death, or other reasons makes the problem of shortage of engineers very critical.

4. Total manpower needs. The number of engineers and engineering technicians employed by the states is affected quite considerably by the practices employed with regard to the states performing its own design work versus having it done by consulting engineers, and of doing its own construction control surveying versus requiring contractors to do it. In 3 states, who do all of their own highway design work, the average number of engineers employed was 4.6 per million dollars worth of construction work. Ohio's figure of 680 engineers for a \$460,000,000 construction program averages only 1.5 engineers per million dollars worth of work. From available figures, it would appear that the total number of engineers employed by all state highway departments and by consulting engineers on highway design work is approximately 34,000.

A state department of highways cannot solve its problem of shortage of engineers and engineering technicians by turning more of the engineering work over to consultants and contractors. Although shifting of these responsibilities to consulting engineers and contractors reduces the number of engineers required by the department of highways, it does not reduce the quality of engineering needed. In fact, a more competent engineer is required to thoroughly and accurately review a set of plans prepared by someone else and to determine that the design is adequate and economical than to "start from scratch" and design a complete project. The highway department needs many top-quality engineers on its staff.

5. Control surveying for engineering construction. Ohio is now requiring the contractors to do a very large percentage of their own control surveying work for construction, furnishing the contractors only with centerline and bench marks. It is more difficult to detect errors in surveying made by another field party than it is to avoid making errors. Consequently, the state highway department must have on its construction projects engineers who are thoroughly familiar with construction projects and who know where and how to check for possible errors or mistakes.

6. Effect of politics in recruitment and promotion of engineers in the state highway department. A high percentage of the engineers who have left the Ohio Department of Highways and likewise of senior-year civil engineering students in Ohio colleges, when voicing reasons why they would not choose to work with the Ohio Department of Highways,

expressed the opinion that politics play too much of a part in the advancement and promotion of engineers.

Because public works projects, such as highways, are paid for by the taxpayers, it is necessary that the administrative head of the highway department be responsible to the public. This is done in all states by having the policy-making person, or persons, in the highway department responsible to an elected official, usually the governor. Thirty-nine states reported that their highway departments are administered through a commission whose members are appointed by the governor. A majority of these commissioners are appointed for terms of 6 years or more and appointed for overlapping terms. In such state highway departments, the engineering personnel are generally free from direct political pressures. The number of positions in the upper echelon of highway departments, filled directly by appointment by the governor, varies from 40 in 1 state, 19 in 1 state, 18 in 1 state, 9 in 1 state, and 1 in each of 13 states. Ohio has 19 men whose positions depend directly on appointment. This observation is in no way intended to imply that the engineers occupying the top 19 administrative positions in the Ohio Department of Highways are anything less than top quality. In Ohio, the present director of highways came out of early retirement, after a full professional career in the highway department. And, if in another election the opposite political party came into power, there is no reason to doubt that competent men would be named to replace those who now occupy the appointive positions. However, the problem insofar as attraction and retention of engineers in the department of highways is concerned, is that young engineers realize that their opportunities for advancement to top positions may depend, to some extent, on politics rather than on demonstrated engineering ability.

7. Analysis of highway administrative organization. The purpose of this study is not to analyze the organization and administrative procedures of the Ohio Department of Highways.

8. Training men for professional engineering competency. A certain percentage of young engineers admit accepting employment with the Ohio Department of Highways primarily for the purpose of obtaining experience that would aid them in obtaining their Ohio professional engineer's license. After this period, they seek employment with contractors, consulting engineers, or other segments of the engineering industry.

FORMAL IN-SERVICE TRAINING PROGRAMS FOR HIGHWAY ENGINEERS

1. Inadequacy of the 4-year bachelor of civil engineering program. Although it is generally agreed by employers of new engineering graduates, by educators, and by professional societies such as the American Society of Civil Engineers that 5 years is needed to obtain a professional engineer's education, the law of supply and demand is effectively forcing schools to provide a program that will allow a student to obtain a bachelor's degree in civil engineering in 4 years. In the 4-year program there is little room for practical courses of application of theory to engineering design or construction problems. To make newly graduated engineers productive, it is necessary for the employer to provide the kind of practical training that the engineer has not received in college. Such training programs will be most effective if organized as formal orientation or in-service training programs.

2. What a formal in-service training program for highway engineers should include. The subject of orientation programs was discussed in considerable depth with the directors of training programs that have been known to be successful in several states. From these discussions, certain observations were made that can be considered as essential for a good program. These include the following: (a) program should continue 24 months; (b) success of the program will vary directly with the quality of administration, leadership, and direction; (c) program should be planned, supervised, and continually monitored by an advisory committee; (d) goals to be accomplished in each phase of the training program must be spelled out specifically so that they are understood in advance by the trainees as well as by the trainers; (e) trainees should be assigned to supervisors in the field who are sympathetic with the aims of the program; (f) the manner in which an individual is initially greeted, made to feel a part of the organization, and oriented has a significant

influence on whether he continues as an employee of the state or resigns; (g) uniform methods and intervals for an evaluation of the trainee's progress should be established; (h) early in the program, an orientation session of 2 or 3 days should be held in which all new trainees are brought together for a series of lectures and seminars; and (i) a formal ceremony should mark the completion of the engineer-in-training program with appropriate recognition and, possibly, the awarding of certificates.

3. Productivity while in training. It is desirable for engineer trainees to be used in productive work as much as possible without diluting or hindering the primary purpose of the program, which is to prepare the new engineers for the assumption of positions of responsibility in the highway department. A fairly large percentage of the trainee's time should be spent on projects in which he is actually producing, or "learning by doing." It is essential, however, that this practical experience be supplemented by and coordinated with a classroom type of schooling. The lecture sessions are fundamental to make sure that trainees thoroughly understand what is going on in the field and why things are done in the way they are. The classroom-type schooling sessions can generally be planned to coincide with times when the trainees are scheduled to be in the central office of the department of highways. Here, organized classes can most easily and effectively be conducted.

4. Advisory committee for continuing education. The in-service training program for a state the size of Ohio is too important, big, and costly to be administered by one man. The training director needs not only staff assistants but also cooperation from all segments of the highway department. To afford guidance to the training director and his staff in the preparation and conduct of all phases of the course, it is recommended that an advisory committee be created. The committee should include representatives of the several sections of the highway department that are most concerned, including the director's office, design, construction, and operations, and a representative from outside the highway department in the education profession. This is the pattern observed in several state highway departments whose training programs have proved to be most successful.

5. Trainee counseling and evaluation. It is important, for several reasons, for the training director to keep in touch with, and be aware of, the progress being made by each trainee.

6. Other programs of continuing education in the department of highways. Engineering technicians, inspectors, project engineers, maintenance supervisors, and practically all other employees of the Ohio Department of Highways need to continue their education. This subject is covered in the next section.

OPPORTUNITIES FOR CONTINUING EDUCATION AND PROFESSIONAL DEVELOPMENT IN THE STATE HIGHWAY DEPARTMENT

1. Keeping up with new knowledge in engineering. New engineering knowledge applicable to road building is increasing at such a rate that it is estimated to be doubling approximately every 10 or 12 years.

2. Participation in continuing education programs. Our survey showed that many states are providing opportunities for engineers to continue their education. Thirty-three percent of the state highway departments report that they make a practice of giving selected engineers time off, with partial or full salary, to carry additional college courses. In 85 percent of the highway departments, the practice is to give time off, with full salary, to attend local, professional technical meetings. Seventy-seven percent of the states allow such time off for attending national meetings.

3. Communication of new knowledge to men who can use it. Generally, only top echelon engineers of most departments of highways are able to attend national technical professional meetings. The information and new knowledge that these top men learn at such meetings and the papers they acquire are of little value unless passed on to the men who can use this new knowledge. Better channels for communication of new knowledge should be established. The annual Ohio Highway Engineering Conference serves as one type of channel. At this conference, reports on new developments in highway engineering, which may have been released by a national organization such as the Highway

Research Board, can be repeated at the local conference, where many younger engineers, who do not attend the Highway Research Board meeting, can hear the presentation. This channel of communications could be improved if all engineers-in-training and other young engineers with the Ohio Department of Highways were required to attend the annual Ohio Highway Engineering Conference and to read papers that are included in the Conference Proceedings.

4. Formal continuing education classes. Another, and perhaps even better, channel of communication of new knowledge to younger engineers would be through formal classroom sessions held as part of the engineering-in-training programs. These formal, in-service refresher courses might best be conducted on specific subjects such as earthwork construction, drainage, portland cement pavements, or bridges. These courses will be of little value unless the teaching effort is well organized, the material is good and well illustrated, and the lectures are well presented.

5. Lecture courses for technicians. Courses for engineering technicians, mostly construction inspectors, could be held for a division or for a group of divisions.

6. Personnel administration seminars for all men in supervisory positions in the state highway department. A course in personnel administration was set up by the Department of Civil Engineering in 1961 for highway administration personnel of the Ohio Department of Highways. This course was repeated several times for groups of administrative personnel in 1961 and 1962. More recently, similar courses have been conducted by the College of Administrative Sciences.

7. Financial support for additional college education. Many state highway departments and the U. S. Bureau of Public Roads have a practice of selecting a few young engineers who show outstanding promise and giving them a term or full academic year of leave of absence for college work toward an advanced degree. These grants usually include an understanding that the employee will return to his previous employer for a minimum specified period of years.

8. Sponsored research at universities. The Ohio Department of Highways, with the assistance of the U. S. Bureau of Public Roads, has been most generous in sponsoring research at universities. Benefits from this program include development of much new knowledge. In addition, this research also develops the interest of many bright young engineers in highway problems and helps the faculty to acquire a better understanding of highway engineering.

ADEQUACY OF UNIVERSITY CURRICULA IN PREPARATION OF CIVIL ENGINEERS FOR EMPLOYMENT WITH STATE HIGHWAY DEPARTMENTS

1. Decreasing number of engineering graduates produced annually by universities. While total college enrollments since 1959 have increased approximately 40 percent, enrollments in engineering have increased less than 3 percent. The period of this drop in enrollment in engineering coincides exactly with the period of changed requirements for accreditation by the Engineering Council for Professional Development (ECPD). Under these requirements, engineering curricula, in order to be accredited, are required to include more science, mathematics, and humanities, and consequently a reduced amount of time spent in courses dealing with practical applications of engineering knowledge.

2. Makeup of civil engineering curricula. The ECPD is governed largely by chemical and electrical engineers, and, under present regulations for accreditation of colleges, this accreditation committee is looking primarily at science-oriented courses. Engineering colleges, forced to graduate men with a bachelor's degree in 4 years, are of necessity making up a 4-year program almost entirely of basic sciences, mathematics, and humanities, with very little course work in practical application of engineering knowledge.

3. Prerequisites for university faculty positions. Under present trends, most engineering college deans seem to feel that all staff members must have PhD degrees. This attitude is contrary to recommended policies of such highly respected organizations as the American Society of Civil Engineers, which is on record as expressing the opinion

that a good and well-balanced faculty should include some members who are engineers with practical experience, irrespective of the degree obtained.

4. Education supplementary to the 4-year bachelor of civil engineering program. It is quite probable that the 4-year program for a bachelor of science degree in civil engineering will be continued in most schools. Even Ohio State University is dropping back from a 5- to a 4-year program. This means that the employer of new college graduate engineers must provide for the continuation of the education needed by the new graduates by providing for them the practical know-how needed to do professional engineering.

CO-OP PROGRAMS, SUMMER EMPLOYMENT, AND UNDERGRADUATE SCHOLARSHIPS FOR CIVIL ENGINEERING STUDENTS

1. Full-time summer work for college students. The summer vacation period for college students generally coincides with the time of the year when construction volume is at a peak. Hence, the use of engineering college students as temporary employees of the state highway department for construction inspection is a natural procedure and is beneficial to both the students and the department.

2. Factors affecting an engineering student's choice of field of specialization. The first year's curriculum in most branches of engineering is so similar that many students do not definitely pick their field until the beginning of the second year of college. If engineering students are employed by the department of highways during the summer vacation following their freshman year, the state has an opportunity to encourage these young men to choose highway engineering. To be favorably impressed, the student must find his work interesting, challenging to his ability, varied, and satisfying through a sense of accomplishment.

3. Orientation course for engineering students completing freshman year at Ohio State University in preparation for summer employment as construction inspectors with the Ohio Department of Highways. This program, conducted by the Department of Civil Engineering of Ohio State University, attracted 183 students in 1966, 110 students in 1967, 136 students in 1968, and 101 students in 1969. A large majority of the students who took the orientation course have indicated that it gave them adequate preparation for their summer work as construction inspectors with the Ohio Department of Highways. This was the primary goal of the course. From conversations with several of our present third-, fourth-, and fifth-year civil engineering students, we have reason to believe that the orientation course and a satisfying summer experience as an inspector with the Ohio Department of Highways were influential in their decision to choose civil engineering as the branch of engineering for their college work and to major in highway engineering. The annual orientation course should be continued.

4. Part-time work during the academic year. Many undergraduate students at Ohio State University work part-time during the regular school year and full-time during vacations in central offices of the Ohio Department of Highways such as the Bureau of Bridges, Bureau of Location and Design, Materials Testing Laboratory, Aerial Photogrammetry Section, and Planning Survey. Supervisors of these young men and women are in positions to cultivate their interest in the Ohio Department of Highways as a place for permanent employment after graduation.

5. Full-time work for a given term such as co-op programs. In the University of Cincinnati's co-op program with the Ohio Department of Highways, a total of 103 students are reported to have participated from 1946 to 1967. As far as can be learned, only 11 of these students have remained with the Ohio Department of Highways. The factors that are appealing or discouraging to co-op students in working with the Ohio Department of Highways are substantially the same as those described earlier for engineering students working during summer vacations from other colleges.

6. Undergraduate scholarship programs. The scholarship program for civil engineering students at the University of Kentucky, sponsored by the Kentucky State Highway Department, has been continuously successful since 1948.

ATTRACTING YOUTH TO STUDY ENGINEERING

1. The state's responsibility for the education of engineers. Part of the problem of the shortage of civil engineers available to state highway departments is the total shortage

of students studying engineering in colleges now and during the past several years. The percentage of students in college who are choosing engineering seems to be decreasing every year.

2. Awareness of the work of the professional engineer. Part of the problem is the lack of awareness of a large percentage of the general public as to what an engineer is or does. A reliable poll showed that less than 6 percent of the public is aware of the work of the professional engineer.

3. High school preparation for studying engineering in college. Possibly one factor that is causing a reduction in the number of students who choose engineering when entering college is that they have not been prepared in high school to face the discipline required to study engineering. Many youths, even though they have a high school diploma, have failed to take the necessary mathematics and science courses that are prerequisites to the study of engineering in college.

4. The industrial arts curriculum project at Ohio State University. An attempt is being made in the College of Education at Ohio State University to develop at the junior high school level a course of study that will create an awareness among pre-high school students of engineering construction as a profession. This course, now being taught in many junior high schools, is called "The World of Construction."

EMPLOYMENT AND TRAINING OF ENGINEERING TECHNICIANS FOR THE DEPARTMENT OF HIGHWAYS

1. Need for more and better trained engineering technicians. Because of the present and anticipated continuing critical shortage of engineers, the state must plan to have more of the subprofessional engineering work done by engineering technicians.

2. Improving the capabilities of currently employed engineering technicians. Many engineering technicians now employed by departments of highways are not producing to the maximum extent of their capabilities. The technicians can generally be classified into 3 groups: (a) beginners, (b) men with 1 or 2 years of practical experience, and (c) experienced technicians who might be prepared to assume more responsibility in work such as construction project administration, design, and materials testing.

3. In-service training courses for engineering technicians now being conducted in other states. Practically every state highway department is making some effort toward providing continuing education for engineering technicians. The extent of the effort and the results vary a great deal. The programs of several states, including Alabama, Georgia, Indiana, Illinois, Kentucky, Michigan, and Virginia, were studied and found to have different approaches to the problem of training technicians. Details of the programs of these states are included in the full report.

4. Instructors for continuing education courses conducted by a state highway department. Many state highway departments use engineers and other departmental personnel as instructors in winter short courses for construction inspectors.

5. Preparatory education of highway engineering technicians in technical institutes. In several states, the department of highways is working closely with established technical institutes or junior colleges in conducting a 2- or 3-year program leading to a certificate of civil engineering technology. The content of the several programs examined are quite similar. The program being followed by the Michigan Technical Institute is shown in detail in the full report. According to the best information available, Ohio now has 8 technical institutes offering certificates in civil engineering technology, and several more institutes are in the process of being formed.

6. The program of the Illinois Division of Highways for training engineering technicians. For the past 12 years, Illinois has conducted a 10-week orientation course each summer for high school graduates who are selected on a competitive basis to prepare them for full-time employment as engineering technicians with the Illinois Division of Highways. This course has been very successful from many points of view: (a) Sixty-two percent of those who have taken the technician course are still employed with the Division of Highways; (b) another 13 percent are on military leave; and (c) 12 percent have left the Division of Highways to return to college to study engineering, and many of these undoubtedly will return to the Division of Highways as engineers.

CONTRACTORS' USE OF CIVIL ENGINEERS AND TECHNICIANS

1. Employment of engineers and engineering technicians by contractors. One of the biggest benefits of the competitive-bid system of highway construction is that the contractors are always searching for better and less expensive ways of doing a satisfactory job. This means that they are looking for the kind of thinking usually found in qualified civil engineers and engineering technicians. The increasing demand for civil engineers by contractors further reduces the number available to state highway departments.

2. Number of civil engineers and engineering technicians now employed by contractors. The construction industry in the United States is big and is getting bigger. For the year of this study, figures reported by Engineering News-Record indicate that the total work done on competitive-bid private contract basis on highway, heavy municipal, and utility projects totaled \$33.3 billion, industrial building construction totaled \$18.1 billion, and residential building totaled \$23.5 billion, for a grand total of \$74.9 billion. The size and ever-increasing sophistication of machines used in engineering construction is such that there is an increasing demand for engineers and engineering technicians to be employed by contractors.

3. College graduates currently employed by general contractors. Figures from our sample study indicate that large general contractors employ an average of 1.185 college graduates per million dollars of work annually; of these, 0.775 are civil engineers. Small general contractors have 1.526 total college graduates and 0.768 civil engineers, and building contractors have 0.890 total graduates and 0.384 civil engineers per million dollars worth of work. Applying these figures to the total construction program for the year of our study indicates that large general contractors employed a total of 20,000 civil engineers; small general contractors, 5,600 civil engineers; and building contractors, 7,000 civil engineers, for a total of 32,600. This is an appreciable number of engineers when compared with 27,273 engineers currently employed by all state highway departments.

4. Additional engineers to be needed by contractors. Our study indicates that contractors will need additional engineers as follows:

<u>Contractor</u>	<u>Within 5 years</u>	<u>Within 10 years</u>
Large general	11,200	27,500
Small general	6,400	10,200
Building	5,700	11,300
Total	<u>23,300</u>	<u>49,000</u>

5. Engineers used by contractors as project supervisors. Information from our sample study indicates that large general contractors employ an average of 1.26 supervisors per million dollars of work annually and that 27.6 percent of these supervisors are engineers; thus, the total number of engineers used as supervisors in 1968 was 9,050. Small general contractors used 1.95 supervisors per million dollars worth of work, of whom 13.8 percent were engineers, or a total of 1,960 engineers. Building contractors used 1.42 supervisors per million dollars worth of work, of whom 12.8 percent were engineers, making a total of 3,290 engineers.

6. What contractors want in preparatory education for engineers. A survey conducted by AGC indicated that most contractors prefer that an engineer have 5 years of college, including all of the basic courses of civil engineering having to do with a knowledge of materials and design and additional courses in personnel management, labor relations, accounting, and economics.

7. Starting salaries offered to engineers by contractors. Large contractors reported offering to civil engineering graduates a minimum starting salary of \$8,000 per year, a maximum of \$12,000, and an average of \$9,100. Small contractors offered a starting minimum of \$6,000, a maximum of \$10,000, and an average of \$7,700. Building contractors offered a starting minimum of \$5,000, a maximum of \$8,000, and an average of \$7,300. By comparison, the starting salaries offered civil engineers with bachelor's degrees by state highway departments, as reported earlier were minimum \$7,272, maximum \$9,624, average \$8,312.

8. Engineering technicians employed by contractors. Large general contractors indicate that they are currently employing 4,450 engineering technicians and within the next 5 years would like to employ an additional 8,900. Small general contractors now employ 4,230 and within the next 5 years would like an additional 10,360. Building contractors now employ 2,930 engineering technicians and within the next 5 years need an additional 12,560.

9. Salaries paid civil engineering technicians. Beginning salaries offered to civil engineering technicians by large general contractors average \$8,900 per year; small general contractors, \$7,500 per year; and building contractors, \$6,500 per year.

10. Continuing education for construction engineering technicians. In several states, contractors' associations, with the support of universities, are holding short courses and workshops during the slack construction season for employees of contractors at the supervisory and foreman level. These courses cover a variety of subjects from general understanding of plans and specifications to special courses in specific areas of work such as flexible pavements, rigid pavements, bridges, and earthwork.

SUMMARY OF RECOMMENDATIONS

The information presented here as observations and conclusions can be further summarized in the form of recommendations as follows:

1. The problem of attraction and retention of engineering talent by a department of highways has so many and such diversified identifiable aspects that it is beyond the capability of one person to fully analyze, much less to solve. It is recommended that an advisory committee on education and training of personnel be established within each department of highways. States that appear to have been most successful in their programs of retention of competent engineers have such committees with a membership that includes not only several persons from the department of highways but, in every case, representatives from the state's civil service commission and the leading state university.

2. The director of personnel training and his staff, working with the advice and counsel of the advisory committee, should initiate several actions as follows:

- a. Secure reasonable guarantees to ensure that engineers are used as engineers, are allowed to use their professional judgment, and are assigned to challenging work.
- b. Provide opportunities for continuing education for present engineers. This can be accomplished by conducting in-service training courses and by providing encouragement and financial support for qualified engineers who desire and opportunity to further their college education in highway-related fields of study.
- c. Provide orientation or engineer-in-training programs for new engineers with the department. Time spent with the individuals in this orientation program, making sure that each is motivated to develop professionally as rapidly as possible, will be a good investment. Recognizing that college graduates from 4-year programs will have had very little preparation for practical professional engineering work, those responsible must carefully design the in-service training program to provide this training.
- d. Provide in-service training programs whereby a fairly large percentage of the trainee's time is spent in productive work where he will be learning by doing. The training program must, however, include classroom sessions on theory of design, intent of specifications, testing of materials policies, and procedures of the department.
- e. Arrange for engineers who are in the engineer-in-training program to attend the annual Ohio Highway Engineering Conference. Trainees should be furnished copies of the proceedings of these conferences and be assigned homework and quizzes on the content.
- f. Take an interest in the teaching of civil engineering in all colleges in the state and assist these colleges in doing a better job of preparing men for work in the highway industry.

- g. Select a few top-quality young engineers and give them encouragement, including financial assistance, to pursue advanced college work with the provision that they will return to the highway department to put their new knowledge to work.
3. Several steps can be taken to attract more engineers to the Ohio Department of Highways. These include the following:
 - a. The Spring Quarter Orientation Program for Freshmen at the university should be continued as desirable preparation for summer employment with the department. Engineers who take the course should be rewarded, possibly with some slightly increased salary over that paid to freshmen who have not taken the course. The engineers who complete this orientation program must be used in meaningful and challenging engineering work. Otherwise, they will be lost to the department as potential full-time employees.
 - b. All state highway departments need to assist, in every way possible, the creation of a better public image of the highway engineer. This can be done through providing assistance programs of education at the junior high school level and by aiding state high school vocational guidance counselors in knowing more about highways.
 4. As the state is forced to use an ever-increasing number of engineering technicians in subprofessional engineering work, programs should be designed to give needed education and training to new engineering technicians and to provide refresher courses for practicing engineering technicians. Efforts should also be made to assist the various technical institutes in the state to do a better job of preparing civil engineering technicians.
 5. Manuals for construction inspectors are needed. These manuals should be prepared in a language that is understandable to the technicians and should be published in a manner that will allow updating as new knowledge is developed and specifications are changed.
 6. Ohio should recognize that the practice of allowing consulting engineers to prepare plans and of requiring contractors to do their own location control means that these 2 groups are going to need more engineers and engineering technicians. The state has an opportunity, and perhaps even a responsibility, to assist in the preparation of qualified engineers and engineering technicians for contractors and consulting engineers.
 7. The key to a continuing good state highway department is the continual upgrading of the capabilities, knowledge, and skills of the employees of the department.

Discussion

KERMIT BERGSTRALH, Roy Jorgensen and Associates—Professor Karrer's paper represents needed research and good research. The data may indicate something other than a critical shortage of engineers in the state highway departments, but the data are valuable. Using Professor Karrer's data, it seems reasonable to conclude that some highway departments may be overstaffed with engineers and maybe using graduate engineers as substitutes for intermediate and advanced technicians. He reports that the state highway departments employed 59,907 technicians and 27,273 engineers in 1968—about 2.2 technicians per engineer. The data also show that Ohio, the only individual department on which employment information was included in the report, employed 3,056 technicians and 680 engineers in 1968—about 4.5 technicians per engineer.

Work sampling techniques have been used to identify the percentages of the bridge design, road design, and construction inspection work loads that require the employment of engineers. The results of these studies vary, but roughly 25 percent of the bridge design work, 15 percent of the road design work, and 10 percent of the construction inspection work apparently must be performed by engineers. These data fluctuate somewhat according to the methods used to perform the design and inspection work, and according to the extensiveness with which computers are used, but few engineers

would place more than 20 percent of the inspection work or more than 30 percent of the design work in the engineering classification.

More than 30 percent of the technical positions in the state highway departments were filled with engineers in 1968, according to Professor Karrer's report.

Graduating engineers gave Professor Karrer many reasons for accepting highway department employment. These 5 reasons were included among the 6 shown in his report:

1. Challenging work,
2. Prospective pay increases and promotions,
3. Opportunities to increase knowledge by experience,
4. Opportunities to use engineering judgment, and
5. Long-range advancement opportunities.

The following 4 reasons were among the 5 listed as the reported reasons for resignations:

1. The work was not challenging,
2. Salaries were too low,
3. Work assignments did not offer opportunities for use of engineering judgment, and
4. Long-range advancement opportunities looked poor.

The real shortage of manpower in the highway departments, if recent work analyses and staffing analyses are correct, is in the advanced technician groups. Nearly 60 percent of the design work requires the employment of well-trained, highly experienced technicians. Although many individual construction inspection assignments can be performed by technicians with limited training and experience, the varieties of those assignments and the ways work loads change on construction projects require the employment of well-trained, highly experienced technicians—or the employment of additional numbers of technicians with limited training so that inspectors capable of doing different kinds of work will always be available when each type of work must be performed. Apparently, if the percentages of intermediate and advanced inspection technicians can be increased, the total numbers of inspectors employed can be reduced, within reasonable limits.

The reasons given for resignations indicate that engineering graduates are being used as substitutes for intermediate and advanced technicians. Obviously, graduate engineers should be given engineering assignments, but this can be very difficult to do. Project design engineers faced with work loads and deadlines must assign the work to personnel capable of doing the work. If adequate numbers of advanced technicians are not available, engineers must be used as substitutes.

Highway departments are having difficulty keeping trained and experienced technicians for 2 principal reasons.

1. As the work to be performed becomes more complex, the numbers of advanced technicians employed must be increased. But the personnel classification specialists find it difficult to increase consistently the percentages of the technician positions allocated to the higher technician classifications. Work analyses show that this must be done, and, when statistical data are collected to prove this point, the classifications usually are changed. Undocumented assurances of the needs for additional advanced positions are not enough.

2. The salary levels of the advanced technician classifications—and of almost all advanced personnel classifications—typically are below the prevailing rates. Entrance salaries usually are equal to or relatively close to going rates, but the funds available for salaries are too limited to permit the payment of prevailing rates to all personnel.

Walter Hjelle, Commissioner of the North Dakota Department of Highways, submitted another paper to the Highway Research Board this year. Commissioner Hjelle reports that his department has adopted a prevailing rate salary plan for all classifications of employment and has financed the essential increases by reducing the numbers of persons employed. The turnover of engineers was reduced from 20 percent to 8 percent as a direct result of the improved salaries.

When salaries are low, the advanced technician and engineering personnel typically receive salaries considerably more out of line with the competition than do the entrance-level personnel. When advanced positions are vacant, additional numbers of entrance-level positions are created and filled. This results in overstaffing with persons who are unable to do advanced technician work, and with graduate engineers who must get the technician work done.

Commissioner Hjelle has suggested an approach that not only is logical but should be fully practical: Determine, by research, the numbers of persons needed at each level of employment to accomplish the essential work, using modern work methods. Identify the salaries being paid by major employers for the needed levels of employment. Employ the numbers of persons needed at the salary levels being paid in the labor markets. Pay the employees for performance and not for years of education and years of experience completed.

As indicated earlier, Professor Karrer's data are valuable. They point up a critical problem in manpower management. Before steps are taken to increase the numbers of engineers employed, however, it should be worth the effort to find out if the engineering work to be done is equal to or in excess of the numbers of engineers employed. Engineering assignments cannot be created without engineering work loads. If managers who are hard pressed to get the work done cannot provide challenging work assignments to the currently employed engineers, there is reason to doubt the need for additional engineers.