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ABSTRACT

This paper provides a review of pertinent statistical information related to supply and demand, a consideration of "forcing" factors in supply/demand analyses, a discussion of training versus task requirements as related to job performance, a presentation of a tentative "engineering occupations" model, and an emphasis on definition of the various elements of the engineering manpower spectrum. (Author/CP)

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ENGINEERING MANPOWER: SUPPLY AND DEMAND ISSUES

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Abstract

A review of pertinent statistical information related to supply and demand; consideration of "forcing" factors in supply/demand analyses; discussion of training vs. task requirements as related to job performance (i.e. what is engineering and who's doing the work); presentation of a tentative "engineering occupations" model; emphasis on definition of the various elements of the engineering manpower spectrum.

INTRODUCTION

It is becoming increasingly clear that the single most critical issue in dealing with engineering manpower problems is that of "definition" (1,2,3,4,5,6). The ever increasing interaction of technology and society (7) with attendant complexity, the recognition that no one practitioner can fulfill all job requirements in an ever growing spectrum of "technical tasks" (8,9), and the clear trends toward increasing professionalization (10) of various elements of the engineering manpower spectrum simply dictate that appropriate definitions must be established and widely utilized by educational institutions, industry and government.

The lack of "definition" continues to plague those interested in supply and demand relationships (1,2,3,4,6,11). In a society where engineers need not be licensed to practice, or those performing "engineering" need not be engineering graduates it is not surprising that there is not agreement on the level of professional engineering education needed to do a given task. Currently, the "explosion" of what might be termed the allied engineering professions (engineering technologists, planners, systems analysts, computer specialists, etc.) only serves to complicate the task of obtaining meaningful supply and demand data (5,12).

Engineering manpower is a critically valuable national resource. Most action to influence the supply of this resource takes a long time to elicit a significant response. Under such circumstances planning is unsurpassingly important to assure provision of the required talents in the quantity and quality necessary when they are needed (13). The aerospace layoffs of the late 1960s and the attendent publicity well illustrate the time lags involved. The engineering enrollment patterns are just now beginning to recover and most studies indicate a subsequent shortfall of engineering and technological personnel in the 1980s (1,12). The spectrum of personnel involved in the layoffs also indicated clearly the problem of definition since many were non-degreed engineers, and had other technical classifications in what may be again referred to as the allied engineering professions.

Good planning requires valid comprehensive data on current manpower trends, valid translation of policies and programs into their manpower implications, and valid simulation models for forecasting manpower demand and supply. Basic to all of this is the need for a clear understanding of the necessary definitions within the engineering manpower spectrum. This paper addresses this definition problem, and then makes an occupational spectrum model comparison between the engineering and health professions.

TRAINING AND TASK REQUIREMENTS

In the world of engineering and technological jobs, there is some distinct attempt to clarify definitions. Although such classifications are also subject to continuous scrutiny and change, there are obviously two major categories involved in occupational classifications (14). These two categories are: (a) those that are job-skilled related, that is, they are descriptive of the task to be performed and (b) those that are worker-skill related, that is, they are descriptive of the background or training required of the worker. We have all seen both kinds of advertisements for employees and are aware of the confusion that often exists. Many times the task description is best and people with a variety of backgrounds can fill a given job. Then again, the training description often, and perhaps usually, asks for over-qualified or over-trained employees, to perform a specific task. In some cases task descriptions are best modified to training descriptions and vice versa.

In some areas, of course, there is no confusion. For example, a doctor employed or retained in industry meets the same qualifications as those in private practice. The legal department of an industry or government also requires the same qualifications as a lawyer in private practice. Although there are certainly specialties within these professions, an individual cannot practice either as a specialist or a general practitioner without meeting specific qualifications, and licensing requirements. And these requirements are distinctly training related, and not task related. This is an important point in trying to understand engineering manpower characteristics, and will be emphasized again within this paper. Lohmann and McCollum have lucidly discussed this point (8,9).

In some areas there is a direct relation between training and task related jobs. If a job description with a naval ship or squadron requires work to be done by an Electricians Mate, then such a rating is requested - the job and training level being both covered by the specific job requirement. It is rare for an individual in such a technical classification to cross over from one rating to another. There are certain jobs requiring certain numbers of personnel. If there are other jobs requiring other types of personnel, then new naval enlistees are encouraged to go into such training and then job positions. They are not trained for positions that have already been filled. Although there are no doubt some problems both with determining tasks and necessary allocations, the system is clearly set up to meet both the needs of the Navy and afford the individual a choice within these defined needs. The needs also change with changing technology. Some ratings get discontinued, others get established or modified. Such is the changing nature of the technological job spectrum within such a technological industry as the Navy.

Several problems exist because of this anomaly between task and training related job descriptions within civilian industries, however. Clearly such a system gives neither (a) explicit attention to employee and student information needs for planning, (b) worker information for job and career selection, and (c) government's information needs for effective public policy decision making (14).

When interpreting manpower and occupational data, the task-related descriptions can often be misleading, because they often cloud the specific training and skills required within the task description. It is interesting to note that representatives of two large "industrial" concerns (one from the manufacturing and one from the power group) both commented on the problems associated with engineering manpower resources, utilization, and educational requirements when "task" definitions for the engineer and "engineering technologist" were essentially the same (15,16).

The engineering profession perhaps suffers most of all from a characteristic job description and training breakdown. At least that is what most of us think. The issue before us concerning specifically the role of the engineer and the engineering technologist has brought this "definition" problem to the fore. As will be seen, however, there is some data to indicate that within engineering and technology the spectrum is hopefully becoming more distinct.

ENGINEERING EMPLOYMENT

The Engineering Manpower Commission has provided over the years the most reliable data concerning engineering and engineering technology enrollments, degrees, placement, etc. Here it is clearly possible to categorize the number of undergraduate and graduate students within specific programs, and thus measure the decline and rise of this source of supply of engineering manpower. Several other characteristics of engineering manpower (as derived from government sources) are of interest in terms of providing a basis for definition of an "Engineering Occupations Model."

The occupational breakdown of engineering employment in 1970 is illustrated in Table I (17). These data clearly indicate that over 70% of engineers, "by occupation," work within industry. The job definition and description problems associated with such a classification have been previously discussed.

Table I

ENGINEERING EMPLOYMENT BY OCCUPATION (1970)

Group	Percent
Manufacturing Industries	53.8
Non-manufacturing Industries	18.5
Engineering and Architectural Service Firms (Consulting Firms)	9.5
Government	13.9
Colleges and Universities	3.8
Non-Profit Organizations	0.5

To place the educational attainment (18) of occupational groups in perspective reference is made to Table II. The engineering occupation had a median school years completed of 16.4 in 1972. This indicates that there are as many occupied as engineers who have in excess of 4.4 years past high school as there are with less than 4.4 years past high school. The medical profession, having specific training related occupational requirements leads the educational grouping with 17.8 schooling years, or 5.8 years beyond high school. It is of interest to note that those occupationally classified as engineering or scientific technicians indicate a median level of at least one year past high school. This perhaps indicates that even the occupational data "hints" at training level organization also.

Table II

EDUCATIONAL ATTAINMENT OF MALE WORKERS (1972)

Occupational Group	Median School Years Completed
All occupations	12.4
Professional, technical, and kindred workers	16.5
Engineers	16.4
Physicians, dentists, and related practitioners	17.8
Health workers except related practitioners	14.6
Teachers, except college	16.9
Engineering and science technicians	13.1
Other professional, technical, and kindred workers	16.4
Manager and administrators, except farm	12.9
Craftsmen, foremen, and kindred workers	12.6
Operatives, except transport, including mines	11.9

Transport equipment operatives	11.6
Laborers, except farm and mine	10.9
Farmers, farm managers, laborers, and foremen	10.3

Another indication of training level within the engineering profession is illustrated in Table III (19). The trend during the 1960's was toward a higher percentage of degreed persons within those occupationally classified as engineers.

Table III

DEGREED ENGINEERS: 1962 and 1972

	(1972) Percent	(1962) Percent
Total Engineers	100	100
No Degree	38	45
Degree	62	55

Although the problems associated with the task-related description have been described previously, it is possible to clarify the engineering-technological occupational spectrum. As the 1970's witness the rapid growth of the area of engineering technology as well as the maturing of the engineering curriculum perhaps into the recommended program toward a first level Masters or Professional Degree, it is of value to present and discuss a preliminary model of this occupational spectrum at this time. Then, in the years to come, it can be modified, adjusted, and clarified.

HEALTH OCCUPATIONS MODEL

There has been much development over the past decade of what might be referred to as paraprofessional or support personnel for the medical profession. These developments have reached the point in the 1970's that a fairly clearly spectrum for the "Health Occupations" has evolved. These data are given in Table IV.

The major professional educational or training level group within the health occupation is, of course, the physician or dentist. No matter what his or her specific field or specialty, his licensing is clearly training related and the data indicate that 430,000 people were in this specific category in 1970. The sub-groups which can be identified as being crucial in support of the major group are listed in the table and have a total of 2,614,000 people, or approximately 6 to 1 in support of the major group. The sub-groups themselves provide professional services and are needed in varying ratios to the main group, from the approximately 2 to 1 nurses to physicians ratio to that of approximately 0.5 to 1 for pharmacists, dieticians, etc. It should be noted that all of these sub-groups require a training-related job classification, except for the health service workers. There is obviously upward mobility within the sub-groups, as health service workers strive to become technologists, nurses, or even doctors.

Table IV

Employment - Selected Health Occupations in the

Experienced Civilian Labor Force (1970)

Occupation	Number 1,000's	Ratio "subgroup" Per Physician
Physicians, dentists and related practitioners	430	—
Registered Nurses	842	1.96
Pharmacists, Dieticians, and Therapists	228	.53
Health Technologists and technicians (clinical, laboratory, health records, dental hytienists, radiology, etc.)	319	.74
Health service workers (aides, practical nurses, trainees, orderlies, etc.)	1,225	2.85
Total (excluding Physicians, dentists, and related practitioners)	2,614	6.07

(Source: Statistical Abstract of the U.S.)

The health occupations spectrum is clear to understand. The data are rigorous, since the professional groupings are specifically training-related and not interpretative from a job-description standpoint.

Engineers, when viewing these data, might wish that the engineering occupations were as clearly defined. Although certainly there are historical factors associated with the complexity of the engineering occupational spectrum, it is possible to see the rudiments of such a spectrum within engineering.

ENGINEERING OCCUPATIONS MODEL

Although the engineering and technological occupations spectrum has rarely been presented in a form as clearly defined as that for the health occupations, it is possible to suggest some occupational and training level groupings that might serve as a first step in defining such an engineering occupations model.

It seems clear from careful inspection of the detailed occupation/employment data given by BLS that there exists a broad spectrum of talent doing the engineering function; albeit, poorly defined and not clearly recognized by all.

If we accept as a reasonable tentative model the relative ratios of the Health Occupations and arbitrarily assign one-third of the reported number of engineers to the engineering technology group (i.e. approximately the number reported as not holding any degree) the data in the last two columns of Table V can be obtained. This model is developed for 1968 data.

The principal thesis here is that since (a) obviously the engineering function is being accomplished and (b) the health occupations model represents a mature example of a well ordered occupational class; then the last two columns of Table V represent a good working hypothesis.

The data in Table 5 are a beginning. Obviously more effort is needed to determine more precise classifications and definitions. It is a hopeful start, however, and shows promise for future development.

Table V

Engineering Occupations Model

Occupation*	1968 Number 1000's	Tentative Model** Suggested Ratio/Engineer	Number 1000's
Engineers	1,100	-	737
Engineering Technologists	NR	2.00	1474
Allied Professionals (e.g. Landscape Architects, Urban Planners, Systems Analysts, Industrial Designer, Surveyors, etc.)	220	.50	369
Engineering and Science Technicians	620	.75	553
Draftsmen	295		
Engineering Service Workers (e.g. treatment plant operators, survey party members, selected craftsmen, manufacturing inspectors, computer operators, etc.)	1,679	3.00	2211
Craftsmen	8,336	-	-

* Groups and numbers from BLS Bulletin 1701.
** Based on Adjusted 1968 Engineers Data.

The problem of definition and the manpower spectrum is a critical issue. Engineers are not alone in facing this definition problem, as teachers and librarians among others are also searching for their own manpower spectrum (21,22). All the professions recognize the importance of such work.

CONCLUSIONS

It is becoming increasingly clear that the prime problem facing the engineering profession is one of definition of the various elements of the engineering manpower spectrum. Not all tasks require the same level of education/training and all those trained/educated to a given level should not be expected to accomplish all tasks.

1. A firm statistical base is essential to every facet of the engineering manpower question.

2. That firm base will not be achieved until we have reasonable well/widely accepted definitions.

3. Supply/demand/model studies may then continue with more precision and will yield:

   (a) employer's information needs for planning,
   (b) worker's information needs for job and career selection,
   (c) educational institution needs for talent development and,
   (d) government's information needs for effective public policy decision making.

4. The "elasticity" in engineering task definition and training/education required to fulfill the task must be reduced if engineering is to achieve the mature professional status it seeks.

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