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ABSTRACT

A study examined the overall structure of Australia's engineering technical work force, the relationships between occupations in each branch and level of the engineering work force, and the job functions of each occupational cluster. The primary purpose of the study was to gather data to assist Technical and Further Education (TAFE) curriculum planners and planners working with other education and training bodies. The analysis was based on two national surveys. The first survey, which was intended to collect general information on the number of workers in each occupational level and branch of engineering, involved a net sample of 1,089 government and industry organizations and 1,090 TAFE and college of advanced education students. The second survey (of a net sample of 1,230 engineering technical workers from all of Australia's states and territories) examined workers' background characteristics and detailed each respondent's job functions. Cluster analysis sorts were carried out by using a statistical rather than a judgmental process, and a cluster diagram was developed after each sorting procedure. Ninety-nine primary clusters were identified. These primary clusters were merged into four major clusters given the following designations: engineering systems and administration (438 respondents), civil engineering and surveying (318 respondents), drafting and design (123 respondents), and electrical and electronic engineering (188 respondents). Job function profiles and background characteristics (including average age, salary, highest education, and proportion of females) were compiled for each cluster. (MN)

TAFE

OCCUPATIONAL CLUSTERS OF THE ENGINEERING TECHNICAL WORKFORCE

- SUMMARY REPORT

GEOFF HAYTON

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FOREWORD

In addition to this summary report, a full report of this project was published by the TAFE National Centre for Research and Development in 1986, and is available through Thomas Nelson Australia in Melbourne. A shorter summary report of this project (excluding the abridged literature review) was also distributed to survey respondents in 1986.

A large number of people kindly assisted in this project in many ways and their contribution is gratefully acknowledged.
The author would particularly like to thank members of the Project Advisory Committee: Jeff Berry, Tony Finnis, Peter Hinkins, Gary LeDuff, Brian Lloyd, Brian Marks, Bill Reaside, Tiiu Salasoo: members of the task inventory team: Bob Andrew, Trevor Davis, Gary Nicholls, Don Overall, Clive Pay, Doug Potts; consultants on computer analysis: Ken Goody and Ray Correll; and Frank Miller and Ed Phelan who commented on the draft report.

The wealth of information provided by the more than 1 000 organisations and 2 000 people who responded in the surveys is acknowledged.

INTRODUCTION

This major study provides information on:

- the overall structure of the engineering technical workforce, including the relationships between occupations in each branch of engineering and between each level;
- the job functions of each occupational cluster and other characteristics that would be of use to curriculum planners in TAFE and other education and training bodies.

The term engineering technical workforce is used to describe all staff primarily performing engineering functions between the levels of tradesperson and professional engineer or surveyor.

The study is the only one of its kind in Australia that has been concerned with the full spectrum of engineering technical workforce occupations Australia-wide. This broad scope has enabled an assessment of which skills may be required across a wide range of occupations and those which are more specialised. It has also enabled information to be obtained on the relationships between the various occupational clusters.

One of the reasons that this study was undertaken was the belief that more attention needs to be paid to the education of the engineering technical workforce. The information provided by this study will be useful to TAFE authorities and other education and training bodies because:

- it provides a sound basis for developing engineering education policies;
- it provides a guideline for planning a range of courses appropriate to the needs of industry;
- it provides data on the skill requirements of the engineering technical workforce in sufficient detail to help in the development of curricula.

Each of these is vitally important if adequate numbers of properly educated engineering technical workers are to be provided. Australia's future as an industrial nation depends on this. The introduction of new technology 'off-the-shelf', without appropriately skilled manpower to adapt and use it in industry, will not ensure that future.

LITERATURE ON ENGINEERING OCCUPATIONAL LEVELS

Occupational levels and terminology

The literature on engineering occupational levels or grades indicates that there is broad agreement, both in Australia and in most overseas countries, on the existence of four levels requiring tertiary education. There is however some variation between the countries in the terms used to describe each level, and some disagreement within Australia on which terms should be used.

People within the first level requiring the least amount of off-the-job education, compared to those in the other levels, are usually termed *tradespeople* or *skilled workers.*

People within the second level are usually termed *technicians* or *engineering technicians*, while those in the third level are usually termed *engineering associates, technician engineers, engineering technologists,* or *technical officers.* In Australia, the term *engineering technical workforce* is used to describe all those in the second and third levels. The broad term used in engineering and other fields to describe the second level is *technician.* The broad term used to describe the third level is *para-professional.*

People within the fourth level, which requires the greatest amount of off-the-job education, are usually termed *engineers* or *professional engineers.*

Table 1 lists the terms used in recent major Australian and overseas studies for each of the four levels, and demonstrates that a variety of terms is being used in Australia for the two middle levels. Indeed, there is even some disagreement on terminology among education and training authorities and other bodies within Australia.

TABLE 1

SUMMARY OF TERMS USED IN RECENT STUDIES TO DESCRIBE EACH ENGINEERING OCCUPATIONAL LEVEL

COMPARATIVE STUDY	U.S.A.	U.K.	AUSTRALIA			QUEENSLAND
French (1981)	Ball & Snarponis (1978) and French (1981)	Connor (1983)	Lloyd, et al. (1979)	IEA & AIEA (1983)	DEIR & ABS (1983)	Henneken, et al. (1983) and Read (1985)
Professional Engineers	Engineers	Professional Engineers	Professional Engineers	Engineers	Engineers	Professional Engineers
Technician Engineers	Engineering Technologists	Technician Engineers	Engineering Associates	Engineering Associates	Technical Officers	Engineering Associates
Technicians	Engineering Technicians	Engineering Technicians	Engineering Technicians	Engineering Technicians	Technicians	Trade Technicians
Tradesmen	Skilled Workers	Engineering Tradesmen	Engineering Tradesmen	Engineering Tradesmen	Tradesmen	Tradesmen

Definition by qualification or job function

There are two approaches to the definition of each engineering occupational level. The first approach, called *definition by qualification* involves specifying the educational qualifications required for each level. This approach provides clear boundaries between each level, and most people can be clearly placed in one occupational level by referring to their educational qualifications. Its main weakness is the difficulty of classifying those with a mixture of formal and informal education, training and work experiences which do not neatly fit the specified qualification.

A further problem is that some people appear to be satisfactorily performing engineering functions at a technician or associate level with qualifications specified for one level lower. The converse also appears to occur, namely, that some people appear to be performing engineering functions at a technician or associate level with qualifications specified for one level higher. (The people in these two groups probably have informal education and training and/or special aptitude which fits them for the job they are performing). .

The second approach, called *definition by job function*, involves specifying the types of job functions performed and breadth of activities to be undertaken at each occupational level. This approach attempts to closely relate the occupational level to the actual job performed, however, a number of studies have experienced difficulties in distinguishing the functions appropriate at each level.

Some writers assert that the laying down of firm boundaries between each occupational level is not realistic and is in fact unhelpful, because the efficient use of new technology in industry requires people with a range of skills which cross these traditional occupational boundaries. The terms 'blurring' and 'multiskilling' are used to describe this phenomenon. It is said that two trends in engineering occupations are occurring in Australia, namely:

- vertical blurring (for example, across the boundary between engineer and engineering associate levels);
- horizontal blurring (for example, across the boundary between mechanical and electronic jobs).

Ford (1986) asserts that overlap or 'blurring' of job functions will be forced upon Australian industry through the introduction of new technology and economic competition.

Education of engineering associates and technicians

In Australia engineering associate level courses are offered in all States, the predominant course taking four years part-time at a technical college. The other main type of engineering associate level course is a two year, full-time course at a college of advanced education, this being most common in Queensland.

Engineering technician level courses are not available in all States. Where they are found, they take two main forms:

- trade-related technician courses - four years part-time taken with indentured apprenticeship;
- office-related technician course - three years part-time.

In those States where formal courses designed specifically for engineering technicians are not available, it is assumed that people in engineering technician occupations usually have either:

- trade qualifications plus appropriate on-the-job training and work experience;
- partial completion of associate level qualifications and appropriate work experience.

In Guidelines on education for the engineering industry, the Institution of Engineers, Australia and the Australian Institute of Engineering Associates (1983) have provided guidelines on education for each of the four categories of engineering occupation, namely, professional engineers, engineering associates, engineering technicians and engineering tradespeople.

PREVIOUS OCCUPATIONAL ANALYSIS STUDIES

In Australia and overseas there have been very few studies on the engineering technical workforce as a whole, while at the same time there have been many studies undertaken of trade occupations and professional engineer occupations.

Most of the studies that have been undertaken in Australia have been restricted to a single State or Territory and to a single branch of engineering. This has made it difficult to obtain a clear national picture of the relationship between the engineering technical workforce occupations in terms of their skill requirements.

The few broad studies in Australia and overseas that have taken place show that:

- two occupational levels exist in the engineering technical workforce;
- engineering technical workers are more concentrated in larger organisations;
- engineering technical workers are more concentrated in government organisations;
- the percentage of females is very low, (less than 3%);
- job functions having a high degree of commonality across occupational groups include:
  - oral and written communication,
  - design and drawing.

None of the engineering technical workforce studies have used cluster analysis to determine the occupational groups on the basis of job tasks performed. Most of the studies have used a broad category of 'job function' to divide respondents into occupational groups. Detailed profiles of each group were provided in some studies that were restricted to a single branch of engineering whereas the broader studies did not provide this level of detail.

RESEARCH METHODS USED IN THIS STUDY

This study involves a review of relevant literature, interviews with TAFE and Training Authority staff and engineering technical workers, and two national surveys.

The first national survey obtained a net sample of 1 089 government and industry organisations and 1 090 TAFE and CAE students and ex-students in all States and Territories. This survey aimed to determine the names of those willing to participate in the second survey, and also to collect broad information on the number of workers in each occupational level and branch of engineering. The second survey obtained a net sample of 1 230 engineering technical workers in all States and Territories. It aimed to determine the background characteristics and detailed job functions of each person.

The method of analysis of the data from the second survey was critical to the whole study, the main method being cluster analysis. Cluster analysis sorts, by a statistical rather than a judgemental process, the respondents into clusters, the members of each cluster having similar job functions. The outcome of a cluster analysis is represented by a cluster diagram, which shows all the resulting clusters and the links between the clusters. The job function profile and background characteristics of each occupational cluster may also be determined and presented in tabular form.

A hypothetical example of a simple cluster diagram is shown in Figure 1.

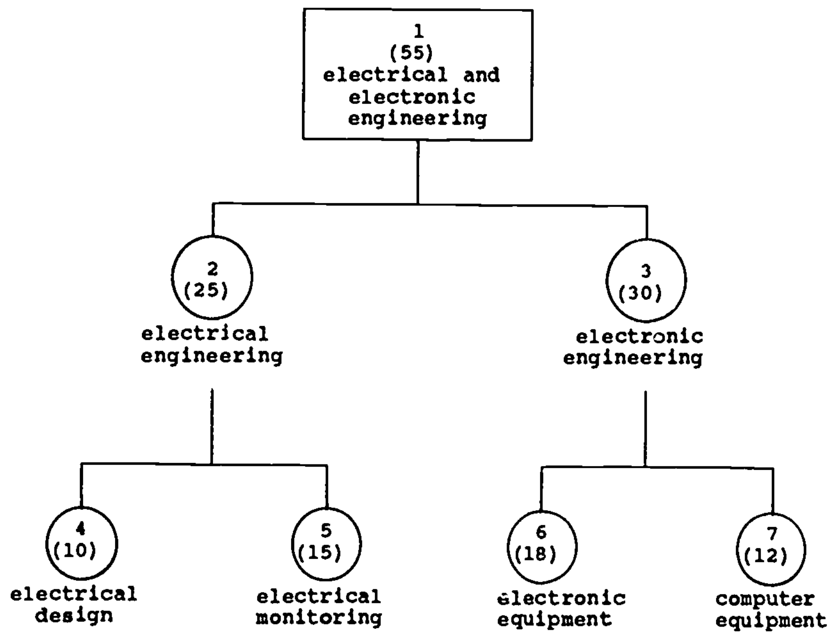


Figure 1: Hypothetical example of the result of a cluster analysis of 55 electrical and electronic engineering workers.

In this example, the number at the top of each box or circle identifies the cluster number. The numbers in parentheses refer to the number of people in each cluster. The lines 'ndicate the links between clusters. Each cluster linked by a line to a cluster above it is a subset of the upper cluster. For example, the 10 people in electrical design joined with the 15 people in electrical monitoring to form a single cluster titled electrical engineering, with 25 people.

MAIN RESULTS

Occupational clusters

The cluster analysis in this study was successful, and resulted in 99 small clusters, termed primary clusters, which were identifiable and clearly able to be interpreted. The hierarchical pattern of the clusters was also meaningful and easy to interpret. Except for a few 'outliers', the primary clusters merged into a number of meaningful intermediate clusters, and these further merged into four major clusters. For example, the intermediate cluster of *electrical engineering* merged with the intermediate cluster of *electronic engineering* to form the major cluster of *electrical and electronic engineering*. The four major clusters were given titles as follows:

- engineering systems and administration (438 respondents);
- civil engineering and surveying (318 respondents);
- drafting and design (123 respondents);
- electrical and electronic engineering (188 respondents)

Figure 2 shows the hierarchical pattern of the cluster analysis, though only the larger clusters are shown because of limited space. The complete diagram is given in Chapter 6 of the full report (Hayton, 1986).

The job function profile and background characteristics (including average age, salary, highest education, and proportion of females) of each occupational cluster are also given in the full report.

NOTES: 1. The number at the top of each box or circle is the 'cluster number' which has been assigned during the clustering process. The numbers in parentheses refer to the number of respondents in each cluster.
2. Only the larger clusters are shown in this summary.

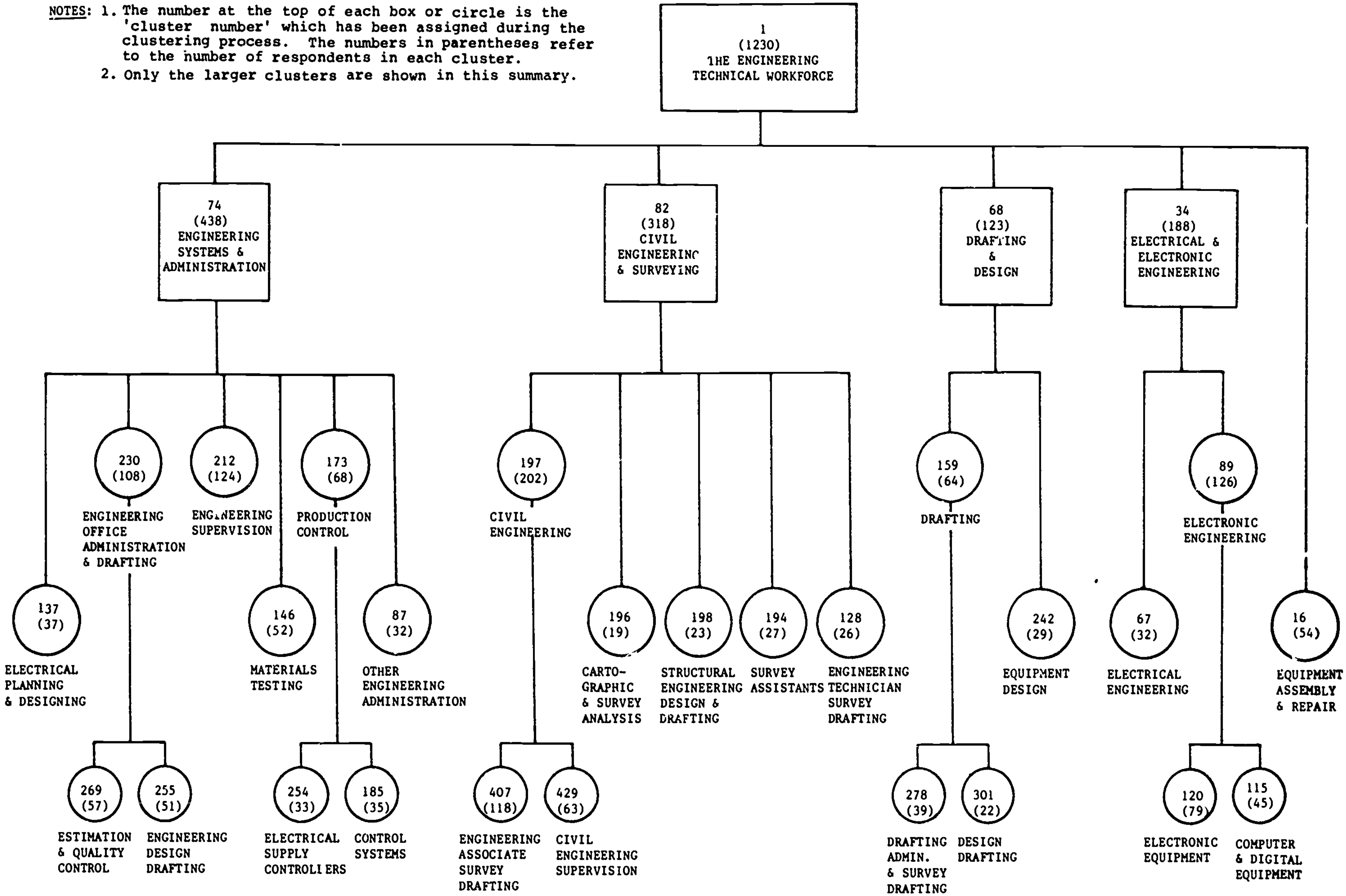


Figure 2: Summary of the cluster diagram.

Other results

Some of the other key findings of the study were that:

- The average age of the engineering technical workforce is 33 years, with an average salary of $23 000 (April, 1985).
- The majority of engineering technical workers are employed by government or semi-government organisations.
- The overall ratio of engineering technical workers to professional engineers was found to be about 1.9 to 1. The ratio of engineering technical workers to engineering tradespeople was found to be about 1 to 1.6. These ratios vary widely between the government and private sector and vary with other factors, such as size of organisation. The total number of employees in each category for the 1 089 sampled organisations is shown in Figure 3.

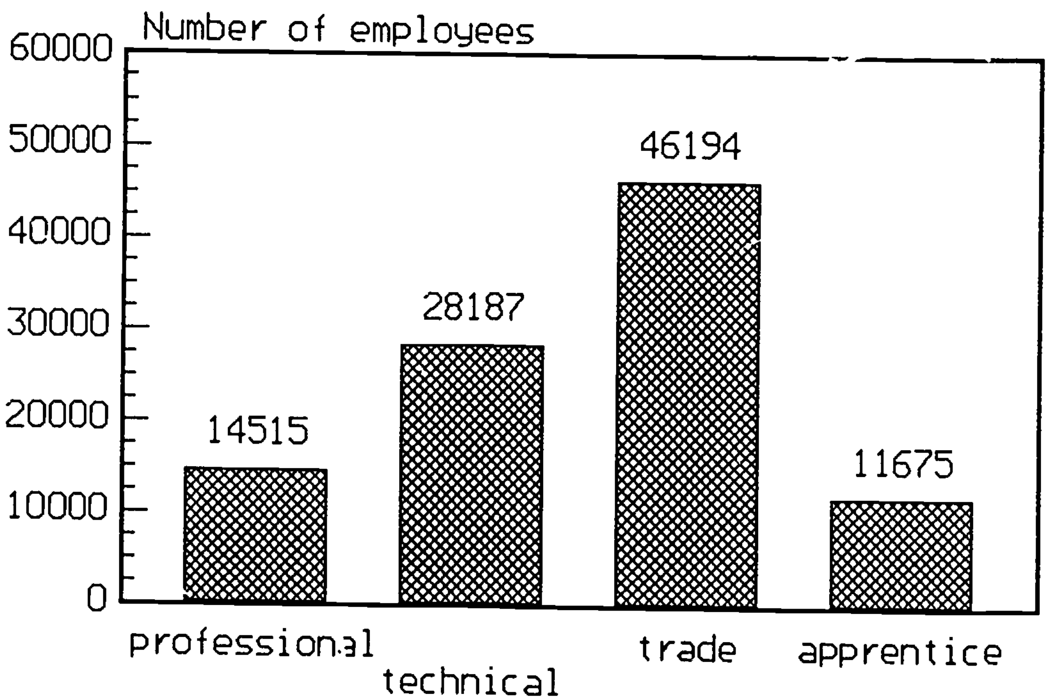


Figure 3: Total number of employees in each category for the 1,089 sampled organisations.

- Government organisations have a higher ratio of technical workers to professional engineers than private organisations, and larger organisations have a higher ratio of technical workers to professional engineers than smaller organisations.
- The percentage of females in the engineering technical workforce was found to be quite low, at 2.6% (see Figure 4). The percentage varied greatly among the different occupational clusters.
- The 621 tasks in the inventory used in the second survey were divided into 61 duties. Of these 61 duties, the five making the highest contribution to the job of the 'average' engineering technical worker were (in descending order of contribution):

  - written communication;
  - oral communication;
  - general administration;
  - the use of calculators and computers;
  - engineering drawing.

- Many of the duties performed by the members of each primary cluster are common to other clusters. The balance of common duties and specialised duties varies among clusters, but over the 99 primary clusters and four major clusters, five of the 61 duties were found to be very broadly performed, being common across the four major clusters, and four were found to very specialised, being performed to any significant degree by the members of just one cluster. Of the 61 duties in the inventory, 15 duties were found to be commonly performed in two or more of the four major clusters. These duties were (in descending order of commonality):

  - written communication;
  - oral communication;
  - general administration;
  - use of calculators and computers;
  - staff supervision;
  - engineering drawing and graphics;
  - design drafting;
  - data collection and analysis;
  - maintenance;
  - finance and estimating;
  - engineering survey drafting;
  - quality testing and measuring;
  - project planning and management;
  - site inspection and investigation;
  - staff development.

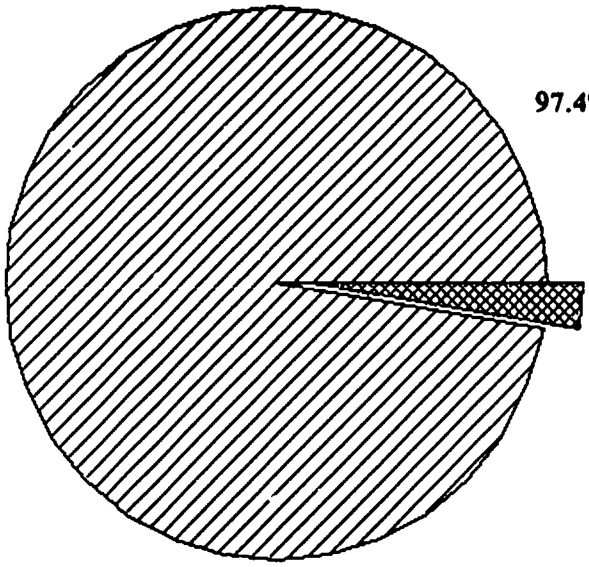


Figure 4: Percentage of males and females in the sample of the engineering technical workforce (n = 1230).

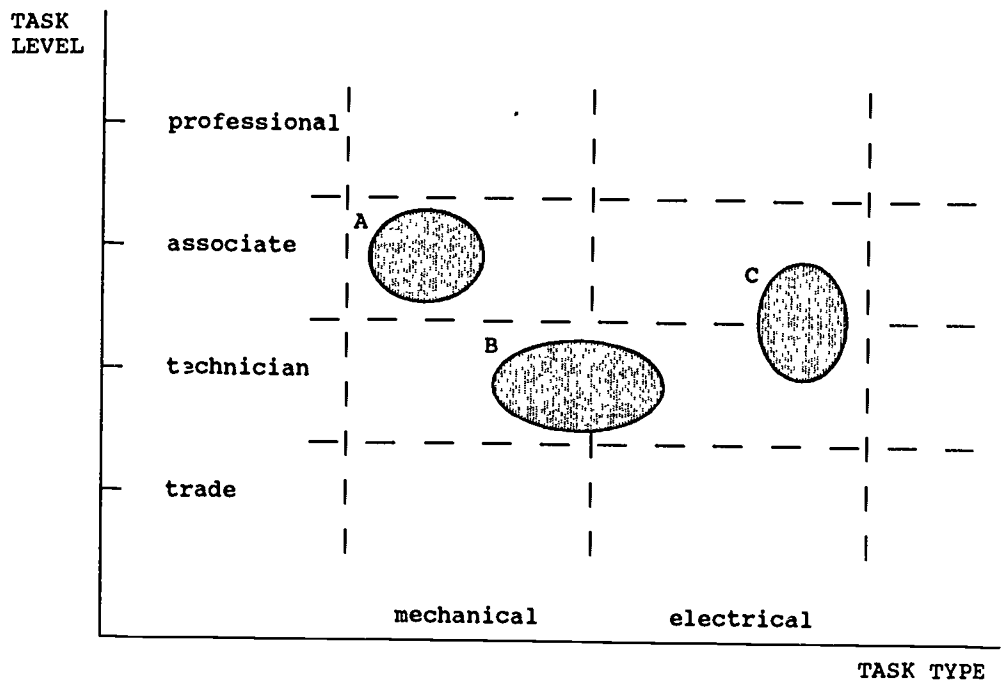
- Two levels may be identified in the engineering technical workforce. People within one level, termed engineering associate level, generally require more formal education and undertake a wider range of tasks than those in the second level. People in the second level, termed engineering technician level, generally require more highly specialised knowledge and skills, and much on-the-job training. Despite this finding, many of the primary clusters were found to consist of members having educational qualifications across the two levels, and performed job functions across the two levels.
- As many as 29 of the 99 primary clusters identified in the study were composed of members requiring a mixture of skills across traditional engineering branches, the most common combination being a mixture of mechanical with electrical or electronic tasks.

These last two findings have important implications for the way education and training programs are designed.

Essentially the study found that the traditional engineering branch boundaries defined many of the occupational clusters, and that the boundary between the levels within the engineering technical workforce also defined many of these clusters. Cluster A in Figure 5 illustrates this type of cluster, which may be termed a single discipline, single level cluster. This basic structure enables specialised courses to be designed to suit the needs of occupational clusters within each branch and level, and the present TAFE course provision largely follows this pattern, although technician level courses are lacking in some areas.

Superimposed on this basic structure is the phenomenon of <u>blurring</u>, in which a significant number of occupational clusters cut across the traditional engineering branch boundaries and across the two levels within the engineering technical workforce. Such blurring is also known to occur in occupations other than engineering occupations. Clusters B and C in Figure 5 illustrate the two types of blurred cluster.

The present TAFE course provision in Australia has, to a large extent, not been flexible enough to closely match the needs of multi-level and multi-discipline occupational clusters, and Recommendations 6 and 7 (given in the next section) address this problem Matching the needs of these occupational clusters does not necessarily mean the provision of 'blurred' courses. What is recommended is the provision of sharply focused courses that meet the various needs of different occupational clusters through flexibility.



NOTE: Cluster A = Single discipline, single level cluster
Cluster B = Multi-discipline cluster (blurring across mechanical-electrical boundary)
Cluster C = Multi-level cluster (blurring across technician-associate boundary)

Figure 5: Three types of occupational cluster.

MAIN CONCLUSIONS AND RECOMMENDATIONS

The full report on this project contains the following main conclusions and recommendations:

Heterogeneous clusters

The clustering process sorted most of the 1 230 respondents into 109 primary clusters. Ten of these clusters were too heterogeneous to be considered as representing a single job type, leaving 99 primary clusters that were easily interpretable. Each of these 99 clusters represents a single job type or occupation in the engineering technical workforce occupations.

The ten heterogeneous clusters represent a population having a diverse range of job types, most being in the area of mechanical, electrical and electronic equipment. All ten clusters were adjacent to the major cluster of Electrical and Electronic Engineering. Further study of these is required to obtain job profiles and information on their education and training needs. It is suspected that formal education does not presently provide well for their education and training needs because of the diversity in their job profiles.

Recommendation 1

That a study be undertaken of the section of the engineering technical workforce represented by the ten heterogeneous outlying clusters found in this study. The purpose of the study should be to determine the job functions and education and training needs of this section of the workforce.

The range of courses required

The primary clusters found in this study represent the spectrum of occupational groups in the engineering technical workforce. This report provides a job profile (at the duty and task level) and profile on background variables of each primary cluster. It is suggested that TAFE and other providers of education and training for the engineering technical workforce compare the needs, represented by these clusters, with their current overall provision of engineering courses. It is likely that suitable education programs are not available for all of these occupational groups in all States and Territories.

Recommendation 2

That TAFE Authorities and other education and training providers use the results of this study to review their current courses for the engineering technical workforce. In particular, the needs of the engineering technical workforce, represented by the occupational clusters found in this study, should be compared with each Authority's overall provision of engineering courses.

Occupational clusters requiring close attention

Ten primary clusters were found to have a high proportion of members having unusual educational qualifications, and this may indicate a gap in the provision of suitable TAFE or CAE courses for the particular needs of the occupational group represented by each cluster. In this study unusual educational qualifications were defined as either:

- completion of <u>other</u> courses (not mainstream TAFE, CAE or University courses) as the highest educational qualification;
- commenced but <u>not continued</u> certificate or associate diploma courses as highest educational qualification;
- blank response to the survey question on educational qualifications (which may indicate <u>no</u> post-school educational qualifications).

The ten primary clusters having a high proportion of unusual educational qualifications are:

- Electronic Engineering Supervisors
- Trade Supervisors
- Materials Test Technicians/Officers
- Electro-mechanical Engineering Officers
- Hydrological Analysis Officers
- Engineering Survey Assistants
- Engineering Survey Drafters
- Senior Microelectronic Maintenance Technicians
- Computer and Digital Equipment Installation Technicians
- Electronic Supervisors

Recommendation 3

In reviewing their engineering courses, TAFE Authorities and other education and training providers should closely examine those occupational clusters in this study signalled as having a higher proportion of unusual educational qualifications.

Common duties

The study found that many of the 61 duties used in the survey were common across a large number of the occupational clusters. Five duties were common to all four major clusters, these duties being:

. written communication
. oral communication
. general administration
. use of calculators and computers
. staff supervision.

In addition, three duties were common to three major clusters, seven duties were common to two major clusters, 18 duties were common to clusters in one major cluster, 24 duties were common to two or more primary clusters only, and four duties were specialised, each being performed in just one primary cluster.

The study was only able to determine the degree of commonality at 'face value'. Duties that are described similarly for two people may in fact be quite different when each person's work is very closely observed and analysed.

The results indicate that common or core curriculum units or modules could, subject to the above qualification, be developed for a range of occupational groups. Areas where low student numbers are likely should be a priority, as common or core curriculum units provide a basis for establishing larger classes.

Recommendation 4

That common or core curriculum modules be developed in those areas judged, on the basis of the results of this study and other information, to be sufficiently common to two or more engineering occupational groups.

Two levels

The study found evidence for the existence of two levels in the engineering technical workforce.

People within one level, termed *engineering associate* level, generally required more formal education and undertook a wider range of tasks than those in the second level. A broader term used to describe this level in engineering and other fields is *para-professional.* People in the second level, termed *engineering technician* level, generally required more highly specialised knowledge and skills, and much on-the-job training. A broader term used to describe this level in engineering and other fields is *technician.*

Some writers suggest that TAFE in general provides well for the needs of associate level occupations but that few courses are provided for technician level occupations. This study provided evidence that many technician level workers have partly completed certificate or associate diploma courses.

This situation is of concern to some writers, who suggest that partly completed certificate or associate diploma courses may not provide an appropriate education for engineering technician occupations, as these courses are primarily designed around the needs of engineering associate occupations. This issue is likely to increase in significance in the future, as many have predicted an increase in the numbers employed in engineering technician occupations.

Recommendation 5

That TAFE Authorities and other education and training providers recognise the existence of two engineering occupational levels between trade and professional level, and that these be termed:

- *engineering technician level;*
- *engineering associate level.*

Further, that education and training programs be provided for occupational groups within each level, appropriate to their particular needs.

Blurring across levels

While there was evidence for the existence of two levels in the engineering technical workforce, many of the primary clusters were found to consist of members having educational qualifications across the two levels, and who had performed job functions across the two levels. For example, when the primary clusters were analysed with respect to:

- highest educational qualification;
- task level;
- number of tasks;

as many as 20 of the 99 primary clusters were classed as 'blurred' across the technician-associate boundary. Of the remainder, 67 were classed as primarily associate level and 12 were classed as primarily technician level.

The blurring across the technician-associate boundary indicates that members of these occupational clusters may require some combination of associate level and technical level education, where separate educational programs are offered for each level. At the very least, transfer between levels should be allowed for and facilitated.

Recommendation 6

In cases where separate educational programs are designed for each of the two engineering technical workforce levels, that:

- *transfer between programs in both directions be facilitated with appropriate amounts of credit allowed;*
- *where modular course design is employed, some modules (optional or compulsory) be made common to both programs to allow for overlapping of levels.*

Blurring across disciplines

The work of the engineering technical workforce, as represented by the task inventory developed for this study, was divided into four broad job function areas. Tasks and duties that were judged to be not specific to a particular engineering discipline were classed in the general area. The other three areas were judged as specialised, these being:

- mechanical/manufacturing,
- electrical/electronic,
- civil engineering/surveying.

Most of the primary clusters performed work in the general area and one specialised area. However, 29 of the 99 primary clusters performed work, to a significant degree, in two or three of the specialised areas. These clusters were termed multi-discipline clusters.

The existence of these clusters and the likely trend towards an increase in 'blurring' across discipline boundaries, have important implications for the design of engineering technician and associate level courses. At present courses are generally structured within one major area. Students requiring skills in a combination of areas may be required to complete a course in one area only and take additional subjects in another area.

A practical approach to this need is to provide educational programs in a modular system, giving sufficient flexibility to allow appropriate programs for both mono-discipline and multi-discipline occupations.

Recommendation 7

That educational programs designed for the engineering technical workforce be designed in a modular system to allow appropriate choice of modules for:

- *mono-discipline; or*

- *multi-discipline;*

occupations. Such programs should comprise appropriate combinations of:

- *common or core curriculum modules;*
- *specialised curriculum modules designed for single-discipline clusters;*
- *specialised curriculum modules designed for multi-discipline clusters.*

Future trends

A number of writers have referred to one or both of the following trends in engineering occupations:

- an increase in the degree of 'blurring', with more occupations requiring skills across two or more engineering disciplines;
- an increase in the numbers required in technician level occupations.

If these trends continue, the results of this study and similar studies will steadily become out-of-date and therefore less useful to TAFE and other education and training providers.

To address this problem, it is suggested that a study or studies be undertaken of present and near future trends in engineering technical workforce occupations.

In addition, a future major study could be conducted of all engineering technical workforce occupations around 1990. The study should employ a methodology similar to the present study, and use the task inventory from the present study. Such a study would provide valuable comparisons with the results of the present study and thus indicate possible longer term trends.

Recommendation 8

That a study or studies be undertaken of present and near future trends in engineering technical workforce occupations, using the results of the present study as a starting point.

That, in addition, a future major study be undertaken of engineering technical workforce occupations around the year 1990, the study using the task inventory from the present study.

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