UNIVERSITY OF CAPE TOWN

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UTILIZATION OF MECHANICAL ENGINEERING MANPOWER IN SOUTH AFRICA

BY

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ABSTRACT

The South African economy is currently experiencing a slow growth rate as a result of amongst other things, a shortage of engineers and technicians.

This study sets out to investigate the present utilization and shortage of mechanical engineers. It was felt that with a comprehensive knowledge of the utilization of mechanical engineers, industrialists would be better equipped to improve productivity by taking the necessary steps to ensure effective utilization of engineering manpower.

The study gathered empirical data, by means of a survey, from seven hundred and sixty seven (767) respondents located throughout South Africa.

The study established that the present utilization of mechanical engineers is about sixty (60) percent and that the most probable cause of the poor utilization is a lack of sufficient technical support staff for the engineer.

Various methods of improving the utilization of mechanical engineers were examined.

The supply and demand for mechanical engineers was reviewed and it was established that the shortage of engineers is very sensitive to variations in utilization.

I, Oswald Schweitzer Wesley Franks, submit this thesis for the degree of Master in Industrial Administration. I claim that this is my original work and that it has not been submitted in this or similar form for a degree at any university.

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INTRODUCTION

1.1 THE PROBLEM

For more than two decades there has been great international concern over the shortage and utilization of engineering manpower - the quality and quantity of this important segment of the labour force and the methods to ensure their most efficient use[1].

In South Africa these concerns have manifested themselves in various research studies, conferences and surveys as indicated below:

- Independent research studies conducted by Ebersohn[2], Terblanche[3] and Cilliers[4] revealed that despite the shortage of engineers in all disciplines, engineers frequently perform activities which could be adequately performed by less qualified personnel such as technicians.

- Annual manpower surveys conducted by the Department of Manpower, and more recently by the Central Statistical Services, have indicated shortages of all types of engineers for more than a decade[5].

- A recent study undertaken by the Human Sciences Research Council (HSRC) projected that the shortage of engineers in South Africa is most likely to continue to the turn of the twentieth century[6].

- As early as July 1965 a national conference held in Pretoria "expressed concern at the shortage of professional engineers" and resolved amongst other things "that all steps be taken to ensure optimal utilization of our technological manpower"[7].

The concerns over the shortage and utilization of engineering manpower are not confined to South Africa.

- In the United States of America, the July 1983 publication of the Scientific Manpower Commission stated "Following a two year investigation, the Business Higher Education forum found that a high demand for engineers in USA will continue through the 1980's".

- The utilization of engineering manpower was given high level attention in America in the early 1960's and in his article Torpey[8] spells out policies adopted by the President of the United States of America in order to bring about improved utilization of Engineers and Scientists. Hirsch[9] suggested that the problems of "shortage" and "utilization" of engineering manpower are interrelated and that the "shortage" of scientific manpower may be due primarily to the inefficient and wasteful use of the present supply.

- More specifically, research conducted by Terblanche in 1982 found that in a sample of 1172 civil engineers about 27% of the work performed by civil engineers could be performed by persons with a lower qualification[10].

1.2 THE AIM AND SCOPE OF THE STUDY

The aim of the study was to empirically establish:

(i) the present utilization of mechanical engineers in South Africa and to determine the extent to which improved utilization could contribute to solving the problem of "shortage" of mechanical engineers,

(ii) the extent to which five preselected factors contribute to poor utilization of mechanical engineers, and

(iii) the nature (administrative or technical) and the level of academic training required by the personnel who could perform certain tasks currently being executed by mechanical engineers.

With the aforementioned aims in mind, the study examined, by means of a literature survey, other relevant aspects which included:

- the historical development of mechanical engineering in South Africa;
- the structure of manpower requirements in engineering and
- supply and demand for engineers.

The study examined the work patterns of mechanical engineers, and the activities they performed were categorised into the following groups:

- Preliminary Investigation
- Development of Design
- Detail Design documentation
- Communications
- Measurement and Estimating

- Investigation and Evaluation
- Project Management
- Maintenance
- Management
- Administration
- Marketing, Promotion and Sales
- Education and Training
- Travel
- Other.

Empirical data made it possible to determine:

- the average time mechanical engineers devote to different activities ie. the manner in which they apportion their time,
- the extent to which the activities performed by mechanical engineers could be performed by less qualified persons,
- the saving of mechanical engineers that could possibly be attained if they were more effectively utilized,

- the nature (technical or administrative) and level of training required by the person performing a portion of the engineers' activities,
- areas of poor utilization, and
- reasons for poor utilization.

A total of 767 respondents participated in the study. It should, however, be emphasized that the survey was confined to mechanical engineers registered with the South African Institution of Mechanical Engineers (SAI Mech E). Therefore, the survey might be biased due to the type of engineers who join SAI Mech E. This study should be considered a pilot study, for further research into similar topics associated with the other engineering disciplines.

1.3 THE CONCEPT OF UTILIZATION

In a study of the utilization of engineering manpower it is necessary to examine exactly what is meant by the term "utilization". The term "utilization" does not embrace a single concept. Hirsch contends that good utilization involves at least two things[11]:

(1) Employing engineering manpower in occupations for which it is well suited by virtue of its ability, experience and education.

(2) Employing engineering manpower so that it is able to make a useful contribution to society.

Any time an engineer carries a piece of test equipment from one location to another, he or she is performing work. This may represent useful work if the instrument is needed at the second location and not at the first, so in a sense, productive work has been performed. However, it is equally obvious that to perform work of the type described, the engineers training was unnecessary. Hence productive utilization could be defined as the performance of that work for which the engineer has had unique training and/or experience.

It is recognised that it would be desirable to discuss present and potential future utilization of engineers in quantitative rather than qualitative terms. When trying to employ such quantitative values however, it is difficult to determine exactly what should be measured, how to perform the measurement, and finally how to validate the measurements. By comparison, in manufacturing terms, if a man is to produce X units of a predefined minimum acceptable quality, in a unit time, his actual output can be compared to X, and efficiency and other rating data can be obtained. Since the output of an engineer mainly comprises the discovery of new facts, the invention of new methods of doing things, or the combination of known concepts to create new devices and mechanisms, against what standard do we measure? Is it correct to say that the engineer who works for forty-five (45) hours per week but rarely produces new ideas is better utilized than one who is absent half the time but makes valuable inventions? What output is to be measured - is it the number of inventions, the number of technical reports, or any one of the many other possible items or forms of output?

The literature on topics related to manpower utilization frequently refers to the benefits which could accrue if improved utilization could be attained(12). However, no previous research, has determined the order of magnitude of improved utilization which might be expected.

Hence, no scientifically established datum for full or 100 percent utilization is known to exist. Realistically, one could not expect to obtain 100 percent utilization of engineers or any other type of human resource.

As opposed to examining the term "utilization" in respect of qualitative or quantitative considerations, utilization may alternatively be viewed from the perspective of labour economics(13). Labour economists have examined the term "utilization" as it is perceived by employers and employees.

Firstly, from the point of view of employers, the term "utilization" refers to the role of engineers in producing an output at minimum cost.

A second point of view regarding utilization is that of the employees. Here, the worker asks "How can I use this occupation to achieve my goals in life?" Obviously, the interest of the employer in cost minimization will not coincide with the goals of the employee who seeks to maximize his or her remuneration.

Having considered utilization from the labour economics view the concept of utilization of manpower remains clouded because of the different underlying interests of employers and employees[14].

The context in which the term "utilization" has been used in this study requires elucidation. In an attempt to establish a quantitative measure of utilization the manner in which the engineer spends his or her working time was examined. The total time an engineer spends at work was taken to be 100 percent. An analysis of the activities performed by an engineer revealed that certain activities performed by the engineer could be performed by a person with less formal education or training than an engineer. Thus for example if it was established that for 30 percent of his working time an engineer performed activities which did not require his level of education or experience then his or her utilization would be reflected as 70 percent. The utilization thus measured could also be referred to as 70 percent efficient utilization as opposed to a 30 percent inefficient utilization.

1.4 THE PERSONNEL IN ENGINEERING : DEFINITIONS

(i) ENGINEER

Commonly the term "engineer" is loosely used in referring to a wide range of engineering personnel who have something to do with electromechanical equipment.

In this study the term "engineer" refers to a person who is competent by virtue of his fundamental academic training, which is normally a Bachelor of Science degree in Engineering (B.Sc Eng) or an equivalent qualification. He applies the scientific method and approach to the analysis and solution of engineering problems with particular emphasis on the development and application of engineering science and knowledge, notably in research, design, construction, manufacturing, administration, management and engineering education.

(ii) PROFESSIONAL ENGINEER

A professional engineer is an engineering graduate who is registered with the South African Council for Professional Engineers (SACPE) and in terms of such a registration is certified to be capable of performing engineering work in accordance with the Professional Engineers Act No. 81 of 1968.

(iii) ENGINEERING TECHNOLOGIST

Chamber's Technical Dictionary defines a technologist as "one skilled in technology, which is the practice, description and terminology of any or all of the applied sciences which have commercial value". The main aspect in which this differs somewhat from the definition of the engineer is that the activity of the technologist is centered mainly on industrial processes while that of the engineer embraces engineering sciences and its applications in all directions. The difference is one of specialized direction rather than one of the level of qualification, and, for this reason, the status of the technologist and the professional engineer is taken to be the same.

Basically his training will also be similar as far as the fundamental aspects are concerned, but it may differ somewhat on the applied side.

The academic qualification associated with the technologist is generally that of the Masters Diploma in Engineering (T5) or a National Higher Diploma (T4) supplemented with appropriate practical experience.

(iv) ENGINEERING TECHNICIAN

An engineering technician is one who is qualified by specialist technical and practical training to work under the general direction of an engineer or technologist. Consequently his academic training, whilst not as broad or as fundamental as that of an engineer or technologist, includes an adequate knowledge of mathematics and applied science related to his own speciality.

The techniques employed demand acquired experience and knowledge of a particular branch of engineering, combined with the ability to work out the details of a task, and he should be competent to instruct and supervise skilled artisans when necessary.

The work of technicians, therefore, includes any of the specialized categories of technical work between those of the artisan and the engineer.

The basic academic qualification of an engineering technician is that of a National Diploma in Engineering (T3) or an equivalent qualification.

1.5 **THE STRUCTURE OF ENGINEERING MANPOWER**

The historical development of the mechanical engineering manpower structure in South Africa is closely related to the mining industry. The discovery of diamonds in 1866 and the subsequent discovery of gold led to the establishment of mines in the Northern Cape and Transvaal regions.

It was from these early mineral discoveries that there sprang the apparently unending demand for engineering manpower.

Initially the mechanical engineering functions associated with the installation, operation and repair of imported mining equipment could be performed by a mechanical engineering technician(15). As the size and layout of plant increased, organizing skill and sounder technical knowledge were required of the person in charge, who also had to assume responsibility for the safe operation of the equipment.

The rapid development towards industrialization after the last war presented new challenges for the mechanical engineer. Whereas in the past they had little need for designing equipment on their own, as such designs were generally forthcoming from overseas, they were now faced to an increasing extent with the problem of having to produce their own solutions and of creating new designs to suit conditions unique to this country. The new equipment so designed had now to be manufactured in the country, and this led to the quick expansion of the manufacturing industry. All this activity called for new qualities in the mechanical engineer which lifted him above the level of the technician, who could, in the early days, cope with most of the problems of operation and maintenance(16).

In the manufacturing industry, the management and administrative abilities of the engineers in charge became just as important to the job as engineering knowledge and the demand for specialized engineers developed.

Mechanical Engineering in the mining industry was characterised by the emergence of the consulting mechanical engineer, attached to a specific mining house, who was responsible for the top-level work, while the practical issues were attended to by mine section engineers(17).

These at first came up through the ranks, but in many cases they were replaced later by more widely trained university graduates. While their work was first carried out on an empirical basis, a scientific approach became more and more necessary as demands for greater outputs at ever greater mining depths, and increased mechanization, became more imperative.

The engineering sector in South Africa is today characterised by the following groups of engineering personnel[18]:

(i) engineers,

(ii) technologists,

(iii) technicians,

(iv) artisans,

(v) operatives, and

(vi) labourers.

The relationship which exists between the various groups of engineering personnel can best be understood by considering the concept of the "engineering team".

The engineering team of the 1980's consists essentially of the engineer, technologist, technician, artisan, operatives and labourers but with no internationally accepted and clearly distinguishable level of education or activity between each.

While it is relatively easy to define a clear boundary between the last three categories, it becomes a little more difficult between the first three i.e. between engineers, technologists and technicians. Reference to the definitions of the functions performed by each category clearly indicates that the functions performed by each group are different(19).

The technician is seen to be performing a supportive role to the engineer thus relieving the engineer from having to perform work which could well be performed by less trained personnel.

CHAPTER 2

LITERATURE SURVEY

2.1 THE APPLICABILITY OF OVERSEAS RESEARCH LITERATURE ON THE SOUTH AFRICAN SITUATION

From the extensive literature survey conducted it has become apparent that the bulk of documented research literature on the utilization of mechanical engineers, available in South Africa, is to a large extent based on findings of studies conducted in America and Europe.

Due to the nature of the research studies conducted in USA and Europe, much of the findings can be of value to South African industrialists and manpower planners. It can expand the knowledge of utilization of mechanical engineers and provide general guidelines as to how the utilization of mechanical engineers may be improved.

The findings of research studies conducted by the Americans, John Merril and Hirsch, et al, have largely been confirmed by South African research work conducted by researchers, S S Terblanche and G Cilliers under the auspices of the Human Sciences Research Council (HSRC).

It is thus safe to assume that much of the research work conducted by American and European researchers has direct relevance to the South African situation with regards to the utilization of mechanical engineers, and an overview of studies conducted locally and abroad would provide significant insight to the research work undertaken by this study.

2.2 A BRIEF REVIEW OF FOREIGN STUDIES CONDUCTED ON THE UTILIZATION OF MECHANICAL ENGINEERS

Hirsch[20], et al, have compiled several tables based on their survey which brought to light the work patterns and time utilization of the engineering personnel included in the survey. In this study which was conducted in the United States of America, 165 questionnaires were sent out to a random sample of engineers who were members of the Institute of Aeronautical Engineers (IAE) and the Institute of Radio Engineers (IRE). The over-all return of questionnaires was 148, representing 89,7 percent of those sent out.

Table I is a breakdown of engineer time expenditure based on the questionnaire.

TABLE 1

PER CENT OF TOTAL TIME DEVOTED TO VARIOUS ACTIVITIES

ACTIVITY	PER CENT
Supervision	26.3
Conferences	14.0
Routine technical work	11.7
Nonroutine technical work	11.7
Report writing	10.3
Nonroutine designing	8.6
Routine designing	3.7
Drafting	3.3
Personal	2.0
Teaching	1.8
Miscellaneous nontechnical work	1.5
Routine laboratory work	0.9
Data searching	0.5
Others and uncertain	3.7
	100.0

The fourteen items in Table I were compiled from various answers to the question of what percent of time was devoted to the various activities.

When the work performed by the engineer requires use of his training or experience, the efficiency of his utilization is high. Hirsch suggested that some activities which do not utilize the unique training of the engineer include:

Drafting

Routine calculations

Routine experimenting or testing

Routine assembly work

Plotting graphs

Routine maintenance

Running errands

Purchasing

Conducting tours

Sales activities

Editing

Recruiting new employees

Formulating routine-type reports

Routine administrative work.

Tables II and III are composites, using data from the questionnaire, providing a positive and negative aspect of how the engineer's time and energies are expended. Accepting the validity of the information contained in Table II, the gross inefficiency of 64,2 per cent indicated in Table III creates a shortage of engineers by requiring three engineers where one properly utilized engineer would be adequate. This reduction of the existing manpower by about two thirds is significant and greatly contributes to any shortage of engineers which may exist.

The employment of engineering technicians who are efficient when they are performing activities in the engineer's low efficiency areas would greatly enhance the availability of engineering manpower.

TABLE 2

PER CENT OF TOTAL TIME SPENT WORKING IN

UTILIZATION CATEGORIES

Activity	Utilization Category		
	Per Cent Efficient	Per Cent Uncertain	Per Cent Inefficient
Supervision		26.3	
Conferences		14.0	
Routine technical work			11.7
Nonroutine technical work	11.7		
Report writing		10.3	
Nonroutine designing	8.6		
Routine designing			3.7
Drafting			3.3
Personal			2.0
Teaching		1.8	
Miscellaneous nontechnical			1.5
Routine laboratory work			0.9
Data searching	0.5		
Others		3.7	
Total	20.8	56.1	23.1

TABLE 3

PER CENT OF TOTAL TIME DEVOTED TO EFFICIENT

AND INEFFICIENT UTILIZATION

Activity	Utilization Category	
	Per Cent Efficient	Per Cent Inefficient
Supervision	6.6	19.7
Conferences	3.5	10.5
Routine technical work		11.7
Nonroutine technical work	11.7	
Report writing	2.6	7.7
Nonroutine designing	8.6	
Routine designing		3.7
Drafting		3.3
Personal		2.0
Teaching	0.5	1.3
Miscellaneous nontechnical		1.5
Routine laboratory work		0.9
Data searching	0.5	
Others	1.8	1.9
Total	35.8	64.2

In their study Hirsch[21], et al, refer to the concept of manpower substitution by suggesting that technicians should perform certain activities which engineers perform inefficiently.

Manpower substitution is taken to mean substitution between different types of labour, defined according to worker traits, abilities, education and training.

In an empirical Canadian study undertaken by Skolnik[22] in 1968, he concluded "that the extent of substitution between engineers and technicians is substantial". The findings of the Skolnik study serves to substantiate Hirsch's proposal with regard to substitution between engineers and technicians.

In addition to the 64 percent inefficiency of engineers, there are other problem areas, some of which are directly related to management and others which are in part due to the nature of engineering as it is accomplished in the United States.

In some cases engineers are used to their fullest capabilities in carrying out a task of work, but there may be no no good reason for the work they are performing. Reasons for the limited value of work performed have been suggested by Hirsch[23] and include poor planning on the part of management or supervisors, or from the deliberate stocking of engineering manpower for some economic reason. In some instances, the qualification of a company for a particular contract is dependent upon the number of engineers immediately available.

Another area of inefficient use of engineering manpower results from duplication of effort. This refers to the efforts expended on the same activities when the duplication is unknown to the parties concerned.

Significant among the reasons for this difficulty is the problem of dissemination and collection of information. Hirsch[(24)] indicated that of those returning the questionnaires, 44 per cent found their activities duplicated at some time in their own companies, and 47 per cent found their activities duplicated elsewhere. It is Hirsch's estimate that from 30 to 85 per cent of scientific time is lost due to duplication of efforts.

According to the engineer profile based on the survey results, the average engineer changes jobs once in every 3,3 years. This would mean a 30 percent turnover per year in an average engineering organization. Besides inordinate expense and company loss of trained personnel, turnover represents a decrease in output by the engineer both at his old and new places of employment. It is not unreasonable to assume that if engineers had an adequate number of engineering technicians to assist them in carrying out their responsibilities, the necessity of job-changing might be reduced in some instances with gains on all sides. This adequate engineer back-up is only speculation, because in many companies technical help or assistance is scarce or unknown.

Seymour Herwald[25] of the Westinghouse Electric Corporation makes the following comment about technicians, "There are two types of technicians. One group will remain technicians all their lives. They will never attain a professional engineering status. The second group will attend school or will otherwise progress in their profession and may eventually become engineers".

That technicians can and do become engineers is further substantiated in an article entitled "Make Your Own Engineers". This article[26] answers the question of whether ability and exceptional experience can be accepted as substitutes for formal education in engineering. The basis of this particular article was observations made over a six year period of a company plan to take care of a two-sided problem, that of helping to satisfy the desires of capable and ambitious technicians and simultaneously enhancing the number of proven engineers within the company. For this company, such a method of upgrading technicians proved satisfactory. The company which achieved this particular solution to the shortage problem is the Airborne Instrument Laboratory, a highly respected and capable company on Long Island, New York, now a division of Cutler-Hammer of Milwaukee. The plan is simply that ambitious and competent technicians are carefully observed, screened, and gradually given additional opportunity for professional recognition within the company and on occasion, during their own time, to attend professional-level courses to round off their technical development.

This article comes to grips with one of the most important aspects of the entire technician program - that in many cases the technician job is only a "stepping stone".

As a result of conferences of engineering management held under the auspices of the U.S. President's Committee on Scientists and Engineers, an effort toward improving engineering manpower utilization has been made(27). The importance of the quality of first-line supervisors of engineers has been emphasized. Accordingly, a re-examination of the supervisory selection method is planned. The conferees were also impressed by the desirability of greater utilization of technicians on the engineering team. Because of these conferences, companies delegated non-professional duties to technicians and clerical employees, trained technicians and recruited more technicians. Without supporting technicians, the engineer defeats the purpose for which he received a particular type of education.

In the supervisory structure of engineering organizations, about 25 percent of all the engineers in a laboratory are required to supervise. Supervisors are frequently selected on the basis of engineering competence, thus decreasing engineering productivity. Engineering competence as the most important criterion for supervision is undesirable.

2.3 A REVIEW OF STUDIES CONDUCTED IN SOUTH AFRICA ON THE UTILIZATION OF MECHANICAL ENGINEERS

It has previously been pointed out that very little scientific research has been carried out on the utilization of engineering manpower in this country.

Research work conducted in South Africa and which has relevance to the study of utilization of mechanical engineers is essentially confined to two published studies undertaken by the Human Sciences Research Council, papers delivered at conferences and a few articles expressing individual opinions on the topic.

However, notwithstanding the limitations of these studies, they do provide a degree of insight to the question of utilization of mechanical engineers and as such have made a very valuable contribution to the present knowledge available.

It is for this reason that the important findings of these studies will now be briefly reviewed.

2.3.1 **<u>S S TERBLANCHE - "THE IDEAL SKILL MIX IN THE CIVIL ENGINEERING INDUSTRY" HSRC 1982 (REPORT NO MR 95)</u>**

This study was carried out within the civil engineering industry on a total number of 1750 respondents consisting of 1172 engineers (67%), 476 technicians (27%) and 102 personnel categorized as "other".

In addition 103 companies in the civil engineering industry supplied data with regards to the structure of their technical personnel.

The main objectives of this study were to determine by means of questionnaire data,

(a) the extent to which technicians could perform the functions of an engineer in the civil engineering industry (i.e. the percentage under utilization of engineers),

(b) the actual ratio of technicians to engineers as depicted by the technical personnel structure of participating companies,

(c) the "ideal" ratio of technicians to engineers and

(d) the factors which contribute to the actual ratio of technicians to engineers varying from the "ideal" ratio.

Terblanche made the following remarks on the findings of his study:

- Engineers clearly felt that they were spending time on functions that could be performed efficiently by technicians.

- Engineers indicated that the non-availability of technicians was an important contributory factor to the inefficient performance of engineers.

- Companies should attempt to increase the training of technicians.

- Respondents generally felt that management did not play an important role in contributing towards the underutilization, of civil engineers, however, management should nevertheless take a careful look at the way they employ their scarce human resources.

With regards to the efficient utilization, engineers felt that they were efficiently utilized for 73 percent of their time i.e. the inefficiency of engineers was 27 percent. The study clearly indicates that for about 27 percent of their time, civil engineers are engaged in activities which could be performed by technicians with a National Diploma qualification. These results do not fully correspond with the findings of the study conducted by Hirsch, et al, where the efficiency of a group of Aeronautical engineers and Radio engineers was found to be 36 percent efficient or 64 percent inefficient.

Possible reasons for this rather large variation in efficiency are:

(1) the level of academic qualification of the technicians may not be the same in each of the studies i.e. in the one case we may be dealing with technicians with a 4 year academic qualification while in the other case the technicians have a 3 year academic qualification.

(2) the perceptions of the respondents with regards to the capabilities of technicians may be very different given the fact that we are considering studies conducted in different countries with different educational systems and different cultures.

The ideal ratio of technicians to engineers as determined by Terblanche in the Civil Engineering industry was 2,4 compared to an actual ratio of 1.

With specific reference to the ratio of technicians to engineers Cambell Pitt [28] wrote that

> "from time to time an attempt has been made to estimate the desired ratio of technicians to professional engineers. I find this an unprofitable task because there are so many factors that influence the ratio".

Pitt's remarks are still valid in so far as the factors which influence the ratio are in-numerable and to a great extent extremely difficult to quantify.

The study identified the following items which could have an influence on the ratio:

(1) The availability of personnel

Here the following factors were identified:

(a) No suitable personnel available in the company

(b) Insufficient suitable personnel available

(c) Impractical for another person to perform part of the job

(d) Poor management

(e) Not sufficient work to keep a person fully occupied.

(2) Technology

The use of latest technology also has implications for saving time. However, few respondents were of the opinion that any significant time saving could be made by using technology not available to them. Typical of the types of technology referred to here are computer draughting and plotting equipment, mini computers and computerised administrative systems.

2.3.2 G CILLIERS - "BENUTTING VAN ELEKTRIESE, ELEKTRONIESE EN MEGANIESE INGENIEURS" HSRC 1985 (REPORT NO MN - 112)

This study was commissioned on representation by the National Manpower Commission in 1984.

The study was based on data provided by 968 respondents drawn from the electrical, electronic and mechanical engineering disciplines.

An analysis of respondents from each discipline is as follows:

TABLE 4

DISCIPLINE OF RESPONDENTS

Engineering Discipline	Respondents	
	Number	%
Electrical Electronic Mechanical	334 284 350	35 29 36
Total	968	100

The main objectives of this study was to establish:

(a) the actual ratio of technicians to engineers in the electrical, electronic and mechanical engineering industries;

(b) the utilization of engineers in each of these industries, and

(c) the availability of the different categories of engineering manpower i.e. engineers and technicians.

The data for this study was obtained by means of a questionnaire. The data was provided by both engineers and employers and it is accepted that an element of subjectivity is built into the results since engineers were providing data with regard to their own activities. However, the main findings of the study applicable to mechanical engineers is reflected below:

(1) <u>Ratio of technicians to engineers</u>

The actual ratio determined by the study was different for the government and private sector.

TABLE 5

RATIO OF TECHNICIANS TO ENGINEERS

Sector	Ratio technicians/engineers
Government	18:1
Private	6:1

These ratio's are surprisingly high and particularly so in the case of the government sector. However, a reason for the higher ratio in the case of the government sector may well be the fact that the nature of the work undertaken by the government sector lends itself to being executed by technicians. The fact that the government sector is engaged in a rather large amount of maintenance work contributes to the high ratio of technicians to engineers since technicians perform associated tasks very efficiently.

(2) Availability of technical personnel

The study found that the government sector experienced greater problems in attracting professional engineers than the private sector. This finding can be accepted and appreciated given the fact that the government sector has a very rigid salary structure whilst more flexibility exists in the private sector.

(3) Utilization of mechanical engineers

The study determined that mechanical engineers are underutilized or inefficiently utilized for 30 percent of their time. This figure corresponds very well with the value of 27 percent obtained by Terblanche in his study on civil engineers. This value is significantly lower than the value of 64 percent obtained by the American study conducted by Hirsch[29] et al, on Aeronautical and Radio engineers.

2.4 GENERAL COMMENTS

Published literature dealing with the topic of utilization of engineering manpower is particularly difficult to obtain. However, this does not necessarily imply a lack of research work on the subject. It might well be the case that studies conducted have never been published. However, the conclusions which can be drawn from the literature surveys conducted are presented below:

(i) engineers are underutilized by an amount which may vary between 27 and 64 percent

(ii) the efficiency of engineers would be greatly enhanced if sufficient support personnel are available to the engineer

(iii) the factors which contribute to poor utilization of engineers are:

- lack of sufficient support personnel,
- duplication of activities and
- ineffective use of engineering technicians.

CHAPTER 3

THE RELATION OF UTILIZATION TO THE SHORTAGE OF ENGINEERS

3.1 A REVIEW OF SUPPLY AND DEMAND FOR ENGINEERS

The primary objective of this chapter is to examine the relation of utilization to the shortage of mechanical engineers. This objective will be attained by considering the following aspects:

- a review of supply and demand for engineers
- the model used to quantify the "shortage" and
- the utilization model.

In order to determine the extent to which inefficient utilization contributes to the shortage of mechanical engineers, it is necessary to examine the manner in which both the "shortage" and the efficiency of utilization are determined.

When the supply and demand for manpower is not in balance then depending on the direction of the imbalance either a "shortage" or a "surplus" is said to exist. This study is concerned with, amongst other things, the case when imbalance in supply and demand for mechanical engineers indicates a "shortage".

Manpower shortages, specifically highly skilled manpower, have the effect of constraining economic growth and contributing extensively to inflation[30].

The extent of the "shortage" of engineers in South Africa has been the subject of wide-spread discussion and controversy for at least the last decade. Much of the disagreement over the issue stems from the variety of meanings attached to the term "shortage" and the model or method used to establish the extent of the shortage.

Blank and Stigler[31] defined a "shortage" and provided an empirical test for establishing the existence of a "shortage". Their definition of a "shortage" is:

> "a shortage exists when the number of workers available (the supply) increases less rapidly than the number demanded at the salaries paid in the recent past".

Rephrasing this definition one, could state that a manpower shortage exists when an excess demand for manpower leads to an increase in wages. However, several problems arise from such a definition. For instance, as a result of the "shortage", less trained manpower such as technicians may be appointed to perform, activities which were once performed by engineers. Since technicians generally command a lower salary than engineers there will be no increase in wages. Thus according to the Blank and Stingler definition no shortage of engineers exists.

Furthermore, Baker[32] showed that this definition does not apply in a monopsonistic market. If there is a monopsonistic situation (or in fact an oligopsonistic situation) in any part of the South African labour market, for instance for certain categories of workers in the civil service, "shortages" may exist without there being any upward pressure on wages.

3.2 FACTORS INDICATING MANPOWER SHORTAGES

Manpower shortages may be indirectly indicated by the following factors:

(i) overtime worked - although overtime generally occurs when the increased demand for manpower is expected to be temporary and is not necessarily an indication of a manpower shortage in the true sense of the word.

(ii) Labour turnover - is another indicator but not a very satisfactory one since different factors cause turnover to be both higher or lower during labour shortages[33].

(iii) Advertised vacancies - may also indicate a manpower shortage. However, advertised vacancies are not good indicators since posts in certain occupations are seldom advertised and also because it is difficult to determine the extent of the shortage when advertisements are of different sizes or the number of vacancies is not indicated in the advertisement.

(iv) Immigration, and finally,

(v) Money spent on recruitment of personnel.

Baker (34) specifies vacancies and relative changes in earnings to be the most important indicators of manpower shortages. Furthermore, Baker contends that manpower shortages and job vacancies are not identical and, therefore, various shortcomings arise when vacancy statistics are used as an indicator of manpower shortages.

In the first instance employers may set unrealistic demands regarding the type of worker required or the wage or salary that is being offered. Vacancies might also exist solely due to normal labour turnover and thus be filled quickly and easily. In these cases a shortage in the true sense of the word does not exist. Another shortcoming is that the shortage might be so serious that employers have ceased to search for workers for a certain occupation and might have taken other measures, e.g. introduced technological changes or applied abnormal and undesirable amounts of overtime. Finally, vacancy data give no indication of shortages which exist as a result of the inferior quality of employees.

In the U.K. and U.S.A. vacancies are determined against the following criteria[35]:

(i) the position must be vacant;

(ii) it should be available immediately;

(iii) some specific recruiting action must have taken place to fill the position;

(iv) it should be available to workers from outside the establishment.

In South Africa, the manpower surveys of the Department of Manpower and more recently by Central Statistical Services are the most important source of vacancy statistics. In the survey, employers are requested to indicate the number of people in their employ in various occupations and also to indicate the number of vacancies that exist in the various occupations.

3.3 THE MODEL USED TO QUANTIFY THE "SHORTAGE"

Models used to determine the shortage of a specific type of manpower generally focuses on quantitative data with regards to the manpower sector being analysed. Qualitative factors also contribute to a "shortage", however, for purposes of this research qualitative factors were not considered in the light of their relative complexity. Thus essentially two models used to determine the "shortage" of mechanical engineers will be discussed.

Firstly, the Federation of Societies of Professional Engineers have conducted annual professional engineering manpower surveys for a period of about eight years (1981-1988). The model employed for determining the demand for engineers is based on the key assumption that vacancies are the result of the difference between demand and supply. Thus if the supply and the vacancies are determined, then the demand is simply the sum of the supply and the vacancies. Hence algebraically stated:

$D = V + S$ or by rearrangement

$V = D - S$ where V = Vacancies

D = Demand and

S = Supply

The annual supply of engineers is determined in even-numbered years from the sum of the following:

(i) the number of engineers graduating at South African universities

(ii) the number of engineers passing or gaining exemption from Part III of the examinations of SACPE, and

(iii) the estimated number of immigrant engineers who are professionally qualified.

The numbers for (i) and (ii) above are obtained directly from universities and SACPE respectively whilst the number of immigrants who are professionally qualified is determined as indicated in Appendix I.

The vacancies are determined in April of the odd - numbered years by a survey carried out by Central Statistical Services. It is assumed that by April the supply of the previous year will have found work.

Figure 1 is a graphical representation of the supply and demand for mechanical engineers for the period 1973 to 1987. The numerical data is contained in Appendix II. Values for 1989 and 1991 were forecasted by the Federation of Societies of Professional Engineers. Figure 1 reflects a shortage of 178 mechanical engineers in 1987.

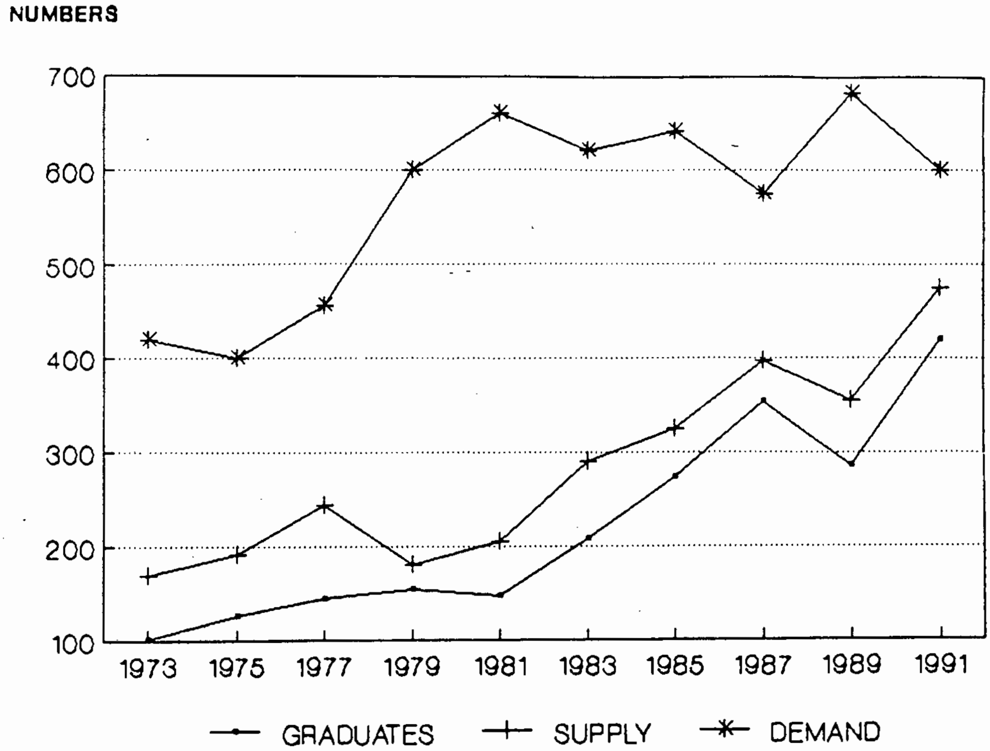


FIGURE 1

SUPPLY AND DEMAND OF MECHANICAL ENGINEERS

The second model for testing the existence of a "shortage" is the Blank and Stigler model which relies on a comparison between the earnings of all engineers and all earners. Blank and Stigler[36] contend that when the earnings of workers in one occupational group increase more rapidly than the general earnings of workers, a strong possibility of manpower shortages in that occupation exists.

However, when using earnings as an indicator of shortage, it is not always clear which measure of earnings should be used[37], e.g. average starting salary, median salary, etc.

There is a lack of data on average earnings of engineers in South Africa and this would further hamper the Blank and Stigler method of determining the "shortage" of engineers.

Both the above models of determining the "shortage" of engineers do not give an indication of the extent to which quality deficiencies are experienced.

3.4 <u>THE UTILIZATION MODEL</u>

Hirsch[38] indicated that the problem associated with developing a model to quantifying utilization of engineers lies in determining what should be measured, how to perform the measurement and how to validate the measurement.

In order to develop an acceptable model for carrying-out this research project it was decided that the model should:

- take account of previous utilization models and
- measure the actual manpower saving that could result from improved utilization of mechanical engineers.

Cillier used a model which lends itself to easy quantification in that utilization is expressed as a function of time devoted to activities which requires the unique training of engineers divided by the total time devoted to work activities by engineers. This model is indicated in figure 2.

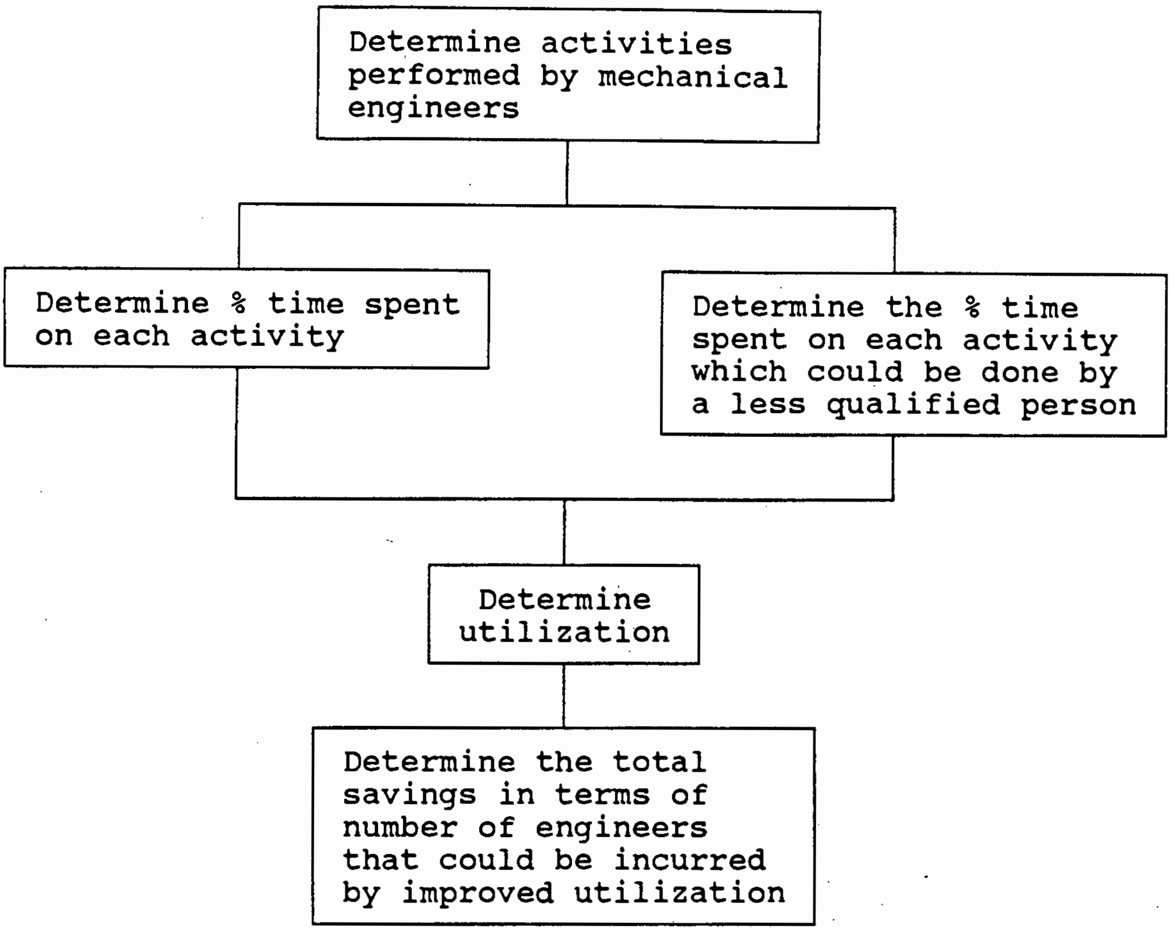
$$\text{UTILIZATION} = \frac{\text{Time spent on activities which employ the unique training of engineers}}{\text{Total time devoted to work activities by the engineer}}$$

FIGURE 2

CILLIER'S UTILIZATION MODEL

Hirsch[39] used the term "utilization" with reference to time consuming activities which do not employ the unique training of engineers. Hirsch regards such activities as ineffective utilization.

The elements comprising the model used to determine the utilization of mechanical engineers in this study are indicated diagramatically in figure 3.



<u>FIGURE 3</u>

<u>THE UTILIZATION MODEL</u>

3.4.1 ACTIVITIES OR JOB FUNCTIONS PERFORMED BY MECHANICAL ENGINEERS

In order to determine the utilization of mechanical engineers it is necessary to analyse the functions or activities they perform in the normal course of their professional duties. For the purpose of this study the various functions performed by mechanical engineers were grouped into three broad categories, each of which requires a different emphasis on engineering science, human relations and economics.

The range of functions performed are indicated in Table 6.

TABLE 6

FUNCTIONS PERFORMED BY MECHANICAL ENGINEERS

GROUP OF FUNCTIONS	FUNCTIONS (ACTIVITIES)	EMPHASIS
THEORETICAL ENGINEERING	. RESEARCH . EDUCATION AND TRAINING . PRELIMINARY INVESTIGATION . DEVELOPMENT OF DESIGN . DETAIL DESIGN DOCUMENTATION	ENGINEERING SCIENCE
PRACTICAL ENGINEERING	. PROJECT MANAGEMENT . MAINTENANCE . INVESTIGATION AND EVALUATION	ENGINEERING SCIENCE HUMAN RELATIONS ECONOMICS
MANAGEMENT	. MANAGEMENT . COMMUNICATIONS . ADMINISTRATION	HUMAN RELATIONS
	. MARKETING PROMOTION AND SALES . MEASUREMENT AND ESTIMATING	ECONOMICS

The functions listed in table 6 were developed to enable any specific activity performed by a mechanical engineer to be appropriately classified.

3.4.2 DISTRIBUTION OF WORKING TIME BY MECHANICAL ENGINEERS

Respondents indicated the percentage of their working time they devoted to each activity as well as the percentage of time devoted to each activity or job function that could be performed by a person with a lesser qualification. Cognisance should, however, be taken of the fact that percentages supplied by respondents were in many cases given in multiples of five or ten thus indicating that they were estimates rather than exactly determined values.

3.4.3 LENGTH OF WORKING WEEK AND NUMBER OF WEEKS WORKED PER YEAR

Additional information required from respondents to establish the time spent on each job function is the actual time devoted to these functions and hence it was necessary to determine the following:

- number of weeks worked per annum and
- the number of hours worked per week.

The product of the above two quantities yields the number of man hours worked per annum.

3.4.4 WORKING TIME DEVOTED BY MECHANICAL ENGINEERS TO FUNCTIONS THAT PERSONS WITH A LESSER QUALIFICATION COULD PERFORM

The time devoted to work which could be performed by persons with a lesser qualification is presented in number of man years and is calculated as follows:

Let a = number of weeks worked per annum

b = number of hours worked per week

$a \times b$ = number of man hours worked per annum

If xi = % time devoted to a specific job function i,

yi = % time of a function i, that a person with a lesser qualification could perform.

mh = man hours

The amount of time that could be saved when a person with a lesser qualification performs a portion of the engineers function is determined as follows:

$$(a \times b) \times \frac{x_i}{100} \times \frac{y_i}{100} =$$ the number of man hours that could be saved if another person performed a portion of the engineers functions

$= mh$

The number of man years which could be saved for each category of job function or activity is expressed as the number of man hours saved divided by the average number of man hours per annum devoted to the specific job function or activity.

Hence,

$$\frac{mh}{(a \times b)/N} = \text{man years saved per job function or activity}$$

where N = the number of engineers performing a specific job function.

The total man years saved would be expressed as:

$$\frac{mh}{(a \times b)/N}$$

For purposes of the study a man year is equated to one mechanical engineer.

CHAPTER 4

THE RESEARCH METHOD

4.1 THE SURVEY SAMPLE

A survey, by means of a questionnaire (appendix III) was conducted of mechanical engineers in South Africa. The survey was made to obtain data which would essentially indicate how engineers are being utilized and how this utilization might be increased.

The total population of mechanical engineers registered with the South African Institution of Mechanical Engineers (SAI Mech E) numbers approximately three thousand and five hundred (3500).

Due to economic constraints, a random sample of two thousand five hundred (2500) mechanical engineers registered with SAI Mech E were sent questionnaires to provide data for the study.

Geographical locations of the questionnaire recipients were limited to the borders of the Republic of South Africa and Namibia.

The final return of questionnaires numbered seven hundred and sixty seven (767) i.e. a return rate of 31 percent. However, not all respondents provided data for each section of the questionnaire and consequently the total responses in these sections of the questionnaire is less than seven hundred and sixty seven (767).

Table 7 provides a complete analysis of replies to the questionnaire.

TABLE 7

ANALYSIS OF REPLIES

REPLIES	NUMBER	PERCENT (%)
Satisfactorily Completed	767	30,7
Unsatisfactorily Completed	32	1,3
Retired or ill persons	24	1,0
Not Returned	1 677	67,0
Total questionnaires	2 500	100

4.2 **PROCEDURE FOR THE STUDY**

Information and data for the study was obtained by both a literature survey and an empirical investigation. The empirical data which formed the basis of this study was essentially gathered by questionnaire. The questionnaire was selected rather than the structured interview method for reasons of economics.

However, it should be pointed out that while the questionnaire may be more cost effective than the structured interview it is also regrettably more subjective. Consequently, the structured interview was used on a very limited scale only to substantiate some of the main trends indicated by the questionnaire.

The study, as initially envisaged, was to be two fold with one questionnaire being sent to mechanical engineers registered with SAI Mech E, and another questionnaire being sent to the management of larger companies employing mechanical engineers.

To this end, two separate questionnaires were prepared. A copy of the questionnaire sent to mechanical engineers is included in Appendix III.

The questionnaire to management was not sent, after many representatives of management indicated that the answers would be difficult to obtain and might be biased to give a good impression of the responding company. However, the questionnaire is included in Appendix IV for information.

The data supplied by respondents to the questionnaire formed the basis of the results of the study.

A random sample of 2500 mechanical engineers were selected from the mailing list of SAI Mech E. The mailing list used, consisted of computer printed stickers which contained the name and postal address of each member.

Each member selected was posted a questionnaire, self addressed envelope and a letter of explanation as contained in Appendix V.

Arrangements were made with the General Post Office (G.P.O.) to have the cost of return post paid for by the researcher.

Questionnaires were sent out during the first week of July 1988 and approximately 60 percent of the response was received by the end of July 1988 (i.e. within three weeks). Only responses received before 1st October 1988 were used in the results. The over-all return of 767 (31%) questionnaires was gratifying.

4.3 VALIDITY OF THE SURVEY SAMPLE

There is always doubt expressed as to the validity and accuracy of expanding a relatively small sample, like the survey discussed here, to cover an entire population or universe. What indications does one have that this sample of 767 is representative of the mechanical engineers working in South Africa and Namibia?

The universe is here taken to mean all professional mechanical engineers employed in South Africa and Namibia. No technically valid comparison can be inferred that this sample is indicative of the entire population of mechanical engineers in South Africa and Namibia. This is unfortunate, but unavoidable, since firstly no complete listing defining the entire population was available from which to obtain a random sample and secondly the research was undertaken with very limited finance.

It should be noted that there might be items in the survey which indicate a skewed result when comparing the results with the entire population of mechanical engineers in South Africa and Namibia. However, despite this, the survey provided appreciably significant results and useful information.

Statisticians state that there is no precise mathematical measure of how well the universe is represented when only one small sample of the universe is available.

An important reason for believing that the 767 response sample obtained in this survey is indicative of the universe considered is the relatively high ratio of responders to those questioned (31 percent). Since the determination of the sample was random, such a high response indicates that any other random sample response will produce approximately the same results.

4.4 THE OBJECTIVE AND STRUCTURE OF THE QUESTIONNAIRE

The study was undertaken to obtain data which would indicate how mechanical engineers are being utilized and how this utilization might be increased. The broad objectives of the questionnaire were to:

- obtain statistical information about mechanical engineers
- determine the mechanical engineers opinion of his/her utilization by the company or employer.

In the formulation of the questionnaire, several successive attempts were made to present it in a form that would be most helpful when analyzing the utilization of mechanical engineering personnel.

Data specifically requested by the questionnaire could be classified into the following five groups:

(i) personal

(ii) professional status

(iii) job functions performed

(iv) time utilization and

(v) causal factors of poor utilization.

The empirical data obtained in groups (i) and (ii) enabled the development of an accurate profile of the survey group. The profile of the survey group include aspects such as its age structure, management structure and academic qualification structure.

The empirical data contained in the remaining three groups is considered to be the essence of the study. The data contained in groups (iii) and (iv) enabled the establishment of work patterns (i.e. total time spent on performing professional activities annually), time devoted to different activities or job functions (i.e. time utilization), variations in time devoted to job functions with years of experience and the efficiency of time utilization by mechanical engineers.

The empirical data contained in group (v) enabled the establishment of the relative importance of factors which result in under utilization or inefficient utilization of the mechanical engineer's time.

Finally, the data contained in groups (iii), (iv) and (v) enabled an evaluation to be made of the impact which inefficient utilization of mechanical engineers has had on the limited engineering manpower of the country.

4.5 <u>ANALYSIS OF RESULTS</u>

According to the literature on analysis techniques, the method of analysis is dependent on the method of inquiry. Statistical analysis techniques for example are said to work successfully in cases where the data has been gathered by means of multiple item questionnaires.

The approach adopted to using the large amount of data collected in the study, was to apply conventional statistical methods to establish whether any definite trends could be discovered.

The counting of opinions was used as the basic method of analysing the information.

The first step in this direction was to get the replies into some form suitable for manipulation by computer.

A computer programme (Appendix VI) was developed using the DBase III Software package.

Data contained on the 767 replies were manually fed into the computer.

CHAPTER 5

RESULTS

The results on utilization of mechanical engineers expressed in the questionnaire of this study are presented under four general headings, namely:

(i) A profile of the survey group

(ii) Utilization of mechanical engineers

(iii) Factors causing poor utilization

(iv) Training requirements of a typical mechanical technician.

5.1 A PROFILE OF THE SURVEY GROUP

The result presented here serves to define the profile of a typical group of mechanical engineers. The survey group provided data related to the following aspects:

- age structure;
- occupational structure;
- management structure;
- academic qualification level;
- remuneration structure, and
- sex classification.

5.1.1 **AGE STRUCTURE**

The age structure of the survey group is reflected graphically in figure 4 and the data which formed the basis of figure 4 is contained in table 8.

The mean age of the total survey group is 40.3 years whilst it varies from 29.2 to 44.8 for each of the occupational groups.

It is noticeable that the mean age of professional engineers (44.8) is rather higher than that of graduate engineers (29.2).

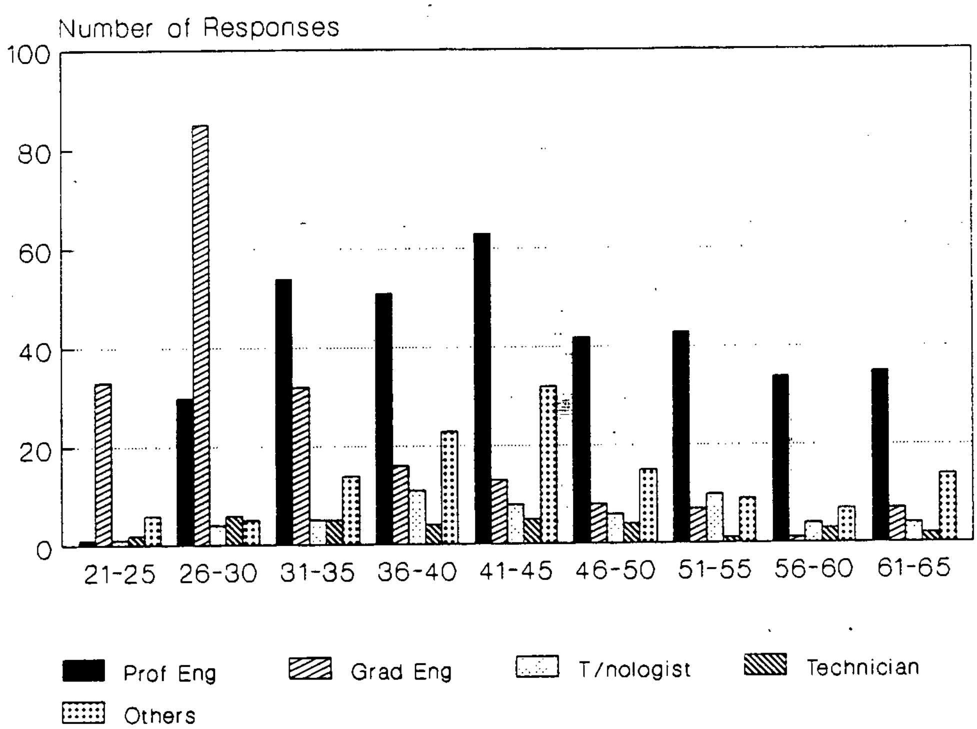


FIGURE 4

AGE STRUCTURE OF SURVEY GROUP

TABLE 8

AGE STRUCTURE OF SURVEY GROUP

AGE	OCCUPATION										TOTAL	
	PROFESSIONAL		GRADUATE		TECHNOLOGIST		TECHNICIAN		OTHER			
	N	%	N	%	N	%	N	%	N	%	N	%
21 - 25	2	0.6	33	16.3	1	1.9	2	6.3	6	4.8	44	5.7
26 - 30	30	8.5	85	41.9	4	7.5	6	18.8	5	4.0	130	16.9
31 - 35	54	15.3	32	15.8	5	9.4	5	15.6	14	11.2	110	14.3
36 - 40	51	14.4	16	7.9	11	20.9	4	12.5	23	18.4	105	13.7
41 - 45	63	17.8	13	6.4	8	15.1	5	15.6	32	25.6	121	15.8
46 - 50	42	11.9	8	3.9	6	11.3	4	12.5	15	12.0	75	9.8
51 - 55	43	12.1	7	3.4	10	18.9	1	3.1	9	7.2	70	9.1
56 - 60	34	9.6	1	0.5	4	7.5	3	9.3	7	5.6	49	6.5
65+	35	9.8	7	3.9	4	7.5	2	6.3	14	11.2	63	8.2
TOTAL	354	100	203	100	53	100	32	100	125	100	767	100
% MEDIAN	45.8 44.8		26.5 29.2		6.9 44.5		4.2 39.5		16.6 43.7		100 40.3	

This difference is to be expected since graduate engineers may only qualify as professional engineers upon completion of at least three years of approved postgraduate engineering experience.

However, many graduates apply for professional status after having gained significantly more than three years of postgraduate engineering experience.

It is also significant to note that 8,2 percent of all mechanical engineers are older than 65 years. Normally 65 years is considered to be the retirement age. It is, however, possible that many of the engineers in the 65 years plus age group have already retired but returned to the labour market.

5.1.2 OCCUPATIONAL STRUCTURE

The occupational structure of the survey group by sector is indicated in tabular and graphical form in table 9 and figure 5 respectively.

Table 9 indicates that 46 percent of the respondents are registered professional engineers whilst 26 percent are graduate engineers. Of the remaining 28 percent of respondents the category "other" represents 17 percent of mechanical engineers while "technologists" and "technicians" represent 11 percent.

Thus, in total, 72 percent of all respondents are either classified as professional or graduate engineers who possess the basic academic qualification to obtain professional engineer status on completion of satisfactory engineering work experience.

TABLE 9

OCCUPATIONAL STRUCTURE OF SURVEY GROUP BY SECTOR

OCCUPATION	SECTOR						TOTAL	
	GOVERNMENT		PUBLIC		PRIVATE			
	N	%	N	%	N	%	N	%
PROFESSIONAL ENGINEER	29	52	53	37	266	48	348	46
GRADUATE	19	34	63	43	116	21	198	26
TECHNOLOGIST	3	5	5	4	44	8	52	7
TECHNICIAN	1	2	7	5	23	4	31	4
OTHER	4	7	16	11	101	19	121	17
TOTAL	56	100	144	100	550	100	250	100

Table 9 further indicates that just more than three quarters (76%) of all professional engineers and just more than half (58%) of all graduate engineers are employed in the private sector.

The ratio of professional to graduate engineers in the private sector is slightly greater than two (2,3) while in the case of the public and government sectors the ratio is less than one i.e. 0,86 and 0,71 respectively. The above ratios clearly indicate the inability of the public and government sectors to compete with the private sector in attracting professional engineers.

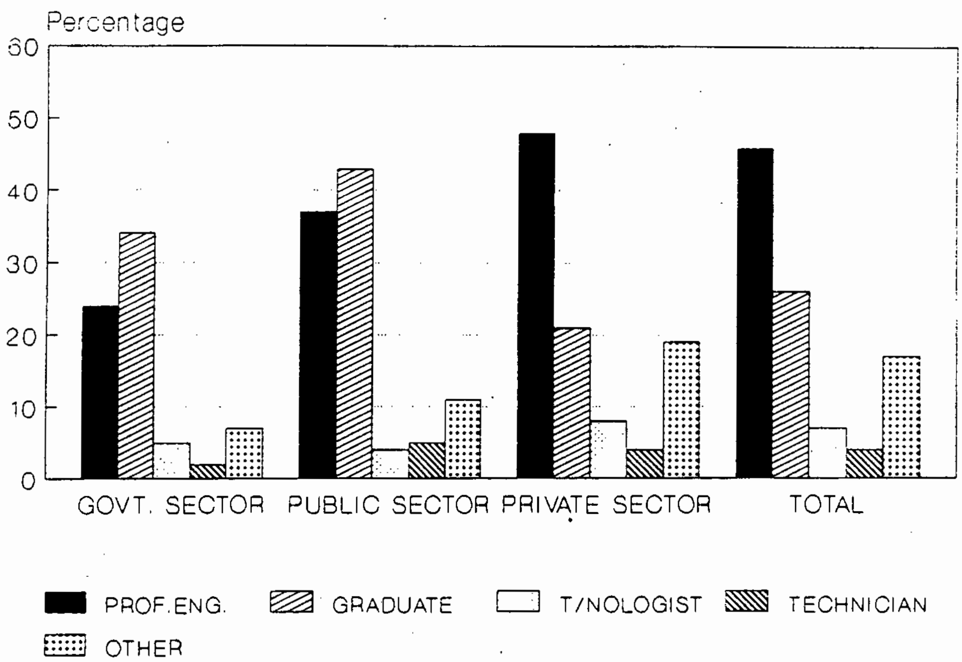


FIGURE 5

OCCUPATIONAL STRUCTURE

The occupational category "other" in the private sector made up 19 percent of private sector engineers. Self employed engineers are indicated in the category "other" hence the relatively large percentage (19%) of this occupational category.

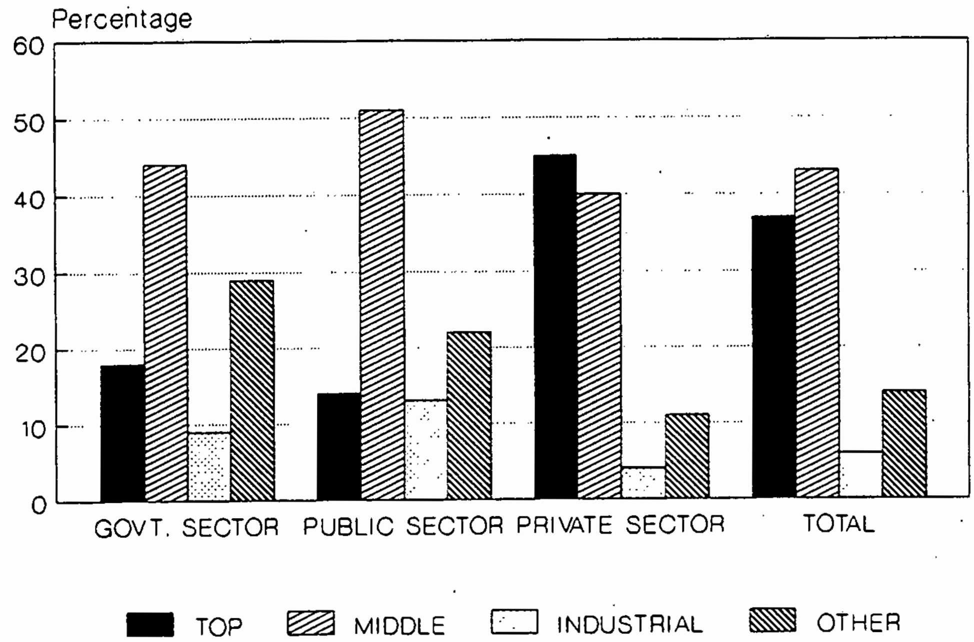
5.1.3 MANAGEMENT STRUCTURE

An analysis of the management structure is indicated in table 10 and figure 6.

The respondents indicated that the following management structure exists:

top management	-	37%
middle management	-	43%
industrial management	-	6%
other	-	14%
		100%

An analysis of the private sector indicates a ratio of top management to middle management of 1,13. This ratio is markedly different from the ratio of 0,27 and 0,41 obtained for the public and government sectors. The ratios less than 1 obtained in the case of the public and government sector is in accordance with expectations since the number of top managers is normally less than that of middle managers.



MANAGEMENT STRUCTURE

FIGURE 6

TABLE 10

MANAGEMENT STRUCTURE OF SURVEY GROUP BY SECTOR

MANAGEMENT CATEGORY	SECTOR						TOTAL	
	GOVERNMENT		PUBLIC		PRIVATE			
	N	%	N	%	N	%		
TOP MANAGEMENT	10	18	20	14	248	45	278	37
MIDDLE MANAGEMENT	25	44	73	51	224	40	322	43
INDUSTRIAL MANAGEMENT	5	9	18	13	24	4	47	6
OTHER	16	29	32	22	59	11	107	14
TOTAL	56	100	143	100	555	100	754	100

The percentage of engineers functioning as industrial managers varied from 4 percent in the case of the private sector to 13 percent in the case of the public sector.

5.1.4 ACADEMIC QUALIFICATION LEVEL

The respondents were required to indicate their academic qualifications in terms of the grouping of educational qualifications indicated in table 11 below.

TABLE 11

ACADEMIC QUALIFICATIONS

GROUP	EDUCATIONAL QUALIFICATIONS	N	%
1	STD 10, (NTC III) NATIONAL TECHNICAL CERTIFICATE	3	0,43
2	NATIONAL TECHNICAL CERTIFICATE IV OR V ADVANCE TECHNICAL CERTIFICATE (ATC I & II) NATIONAL CERTIFICATE FOR TECHNICIANS NATIONAL HIGHER CERTIFICATE FOR TECHNICIANS (NCT) INTERMEDIATE DIPLOMA FOR TECHNICIANS (IDT)	0	0
3	NATIONAL TECHNICAL DIPLOMA (NTD) NATIONAL ENGINEERING DIPLOMA HIGHER NATIONAL CERTIFICATE FOR TECHNICIANS (IDT)	6	0,87
4	NATIONAL DIPLOMA FOR TECHNICIANS (NDT) HIGHER NATIONAL DIPLOMA FOR TECHNICIANS GOVERNMENT CERTIFICATE OF COMPETENCY NATIONAL DIPLOMA NATIONAL HIGHER DIPLOMA	136	19,6
5	BACHELORS DEGREE IN ENGINEERING MASTERS DIPLOMA IN TECHNOLOGY	374	54,0
6	POST GRADUATE QUALIFICATION	174	25,1
		693	100

It should be understood that the grouping of academic qualifications as per table 11 is not intended to equate the different qualifications, however, the grouping is merely an attempt, for purposes of this research, to evaluate the different qualifications in terms of number of years of study.

Table 11 indicates that a quarter of the respondents are holders of an academic qualification which is evaluated as a post graduate qualification i.e. a qualification evaluated as matric plus five or six years of study.

Respondents who indicated their qualification as a Baccalaurus degree in Engineering (or an equivalent qualification) formed 54 percent of the survey group whilst the holders of a three year post matric qualification made up 19,6 percent.

Hence just under 80 percent of respondents are holders of an academic qualification which is, for purposes of this study, considered to be equivalent to a B.Sc Eng or a higher level qualification.

Table 12 gives a comprehensive analysis of the educational qualification of the survey group for each sector (private, public and government).

Table 12 further indicates that the bulk of the more highly qualified mechanical engineers are to be found in the private sector.

TABLE 12

QUALIFICATION LEVEL OF SURVEY GROUP BY OCCUPATION

OCCUPATION	QUALIFICATION LEVEL													
	1		2		3		4		5		6		TOTAL	
	N	%	N	%	N	%	N	%	N	%	N	%	N	%
GOVERNMENT SECTOR														
PROFESSIONAL ENGINEER							3	50.0	14	42.0	11	92.0	28	53.0
GRADUATE ENGINEER									16	46.0	1	8.0	17	32.0
TECHNOLOGIST							1	16.6	2	6.0			3	5.6
TECHNICIAN							1	16.6					1	1.8
OTHER					1	100	1	16.6	2	6.0			4	7.6
TOTAL					1	100	6	100	34	100	12	100	53	100
PUBLIC SECTOR														
PROFESSIONAL ENGINEER							3	16.0	30	35.0	17	57.0	50	37.0
GRADUATE ENGINEER	1	100							52	60.0	9	30.0	62	46.0
TECHNOLOGIST							3	16.0	1	1.2			4	2.9
TECHNICIAN							4	21.0	1	1.2			5	3.6
OTHER							9	47.0	2	2.8	4	13.0	15	10.5
TOTAL	1	100					19	100	86	100	30	100	136	100
PRIVATE SECTOR														
PROFESSIONAL ENGINEER							19	25.0	141	55.0	87	66.0	257	50.4
GRADUATE ENGINEER							9	8.0	80	31.0	34	18.0	113	22.2
TECHNOLOGIST					1	20.0	26	23.0	6	2.3	2	1.5	35	6.8
TECHNICIAN					2	40.0	13	22.0	2	0.8			17	3.3
OTHER	2	100			2	40.0	34	32.0	25	14.5	19	14.5	88	17.3
TOTAL	2	100			5	100	111	100	254	100	132	100	510	100
ALL SECTORS														
PROFESSIONAL ENGINEER							35	25.7	185	49.5	115	66.1	335	48.5
GRADUATE ENGINEER	1	33					9	6.6	148	39.6	34	19.5	192	27.7
TECHNOLOGIST					1	17.0	30	22.1	9	2.4	2	1.2	42	6.1
TECHNICIAN					2	33.0	18	13.2	3	0.8			23	3.3
OTHER	2	67			3	50.0	44	32.4	29	7.7	23	13.2	101	14.6
TOTAL N	3	100			1	100	136	100	374	100	174	100	693	100
TOTAL %	0.43		0		0.87		19.6		54.0		25.1		100	

5.1.5 **REMUNERATION STRUCTURE**

The remuneration structure of the total survey group is indicated in table 13.

The analysis of remuneration indicates that more than 77 percent of mechanical engineers are remunerated in excess of R40 000 per annum.

The distribution of salary as indicated by the data is not a normal distribution and is rather heavily skewed to the upper limit of the remuneration scale.

TABLE 13

REMUNERATION STRUCTURE OF SURVEY GROUP BY OCCUPATION

OCCUPATION	REMUNERATION (RANDS x 1000)												TOTAL	
	<20		20-25		26-30		31-35		36-40		>40			
	N	%	N	%	N	%	N	%	N	%	N	%	N	%
PROF. ENGINEER	3	16.6	4	19.0	3	10.7	10	22.2	16	26.2	312	54.2	348	46.7
GRAD. ENGINEER	9	50.0	13	62.0	20	71.5	26	57.7	27	44.3	102	17.7	197	26.4
TECHNOLOGIST			1	4.8			1	2.2	9	14.8	40	6.9	51	6.8
TECHNICIAN	2	11.1	1	4.8	3	10.7	5	11.3	2	3.2	18	3.1	31	3.8
OTHER	4	22.3	2	9.4	2	7.1	3	6.6	7	11.5	103	18.1	121	16.3
TOTAL	18	100	21	100	28	100	45	100	61	100	575	100	748	100

Professional engineers are the more highly remunerated occupation sector with about 90 percent being remunerated in excess of R40 000 per annum.

5.1.6 **SEX CLASSIFICATION OF SURVEY GROUP**

The classification of the survey group according to sex is indicated in Table 14 below.

TABLE 14

SEX CLASSIFICATION OF RESPONDENTS

SEXUAL CLASSIFICATION	N	%
MALE	753	98,2
FEMALE	14	1,8
	767	100

Females make up just under 2 percent of all respondents whilst males form just more than 98 percent.

5.2 UTILIZATION OF MECHANICAL ENGINEERS

The results of this section of the study deals essentially with the quantification of "utilization" of mechanical engineers and is presented under the following four headings:

- Percentage time devoted to various activities
- Time devoted to inefficient activities
- Actual time devoted to each activity per annum and
- Total saving of time and manpower.

5.2.1 PERCENTAGE TIME DEVOTED TO VARIOUS ACTIVITIES

The work patterns of mechanical engineers was analysed on the basis of time devoted to various activities or job functions. For purposes of this study a list of twelve (12) activities were used as a basis of the analysis. The activities are listed in table 16. The twelve (12) activities were further classified into three (3) broad groups of functions (viz practical engineering, theoretical engineering and management) as per table 15.

Mechanical engineers were requested by question 10A of the questionnaire to indicate the average percentage of working time which they devote to each of the activities or job functions indicated in table 16. Using the information contained in table 16 and classifying each activity into a group of functions table 15 was developed.

Remarkably little variation in the distribution of engineers' time is indicated by table 15.

Without exception the percentage of time devoted to management functions is the highest. Time spent on management functions ranges from 46 percent in the case of technologists and graduate engineers to 54 percent for professional engineers.

TABLE 15

PERCENTAGE OF TIME DEVOTED TO FUNCTIONS

GROUP OF FUNCTIONS *	PROFESSIONAL ENGINEER	GRADUATE ENGINEER	TECHNOLOGIST
THEORETICAL ENGINEERING	26	34	32
PRACTICAL ENGINEERING	20	20	22
MANAGEMENT	54	46	46
	100	100	100

* The activities categorised under the "groups of functions" in table 15 may be found in table 6 on page 47.

Practical engineering demands 20 percent of the time of both graduate and professional engineers whilst in the case of technologists it is 22 percent.

TABLE 16

AVERAGE PERCENT OF WORKING TIME SPENT ON EACH JOB FUNCTION BY SURVEY GROUP

JOB FUNCTION	PROFESSIONAL ENGINEER	GRADUATE ENGINEER	TECHNOLOGIST
	N=351	N = 199	N = 52
	%	%	%
1. PRELIMINARY INVESTIGATION	8	8	8
2. DEVELOPMENT OF DESIGN	8	12	10
3. DETAIL DESIGN DOCUMENTATION	4	7	8
4. COMMUNICATION	9	10	10
5. MEASURING AND ESTIMATING	3	4	6
6. INVESTIGATION AND EVALUATION	4	4	6
7. PROJECT MANAGEMENT	11	10	9
8. MAINTENANCE	5	6	7
9. MANAGEMENT	23	13	12
10. ADMINISTRATION	8	7	8
11. MARKETING SALES	5	5	13
12. EDUCATION AND TRAINING	6	7	6
13. TRAVEL	3	3	3

Management is clearly the single activity to which engineers allocate the highest percentage of their time. Time devoted to the management activity varies from 23 percent for professional engineers to 13 and 12 percent for graduate engineers and technologists respectively. By inspection of Table 16 it is evident that other activities to which the mechanical engineer devotes a high percentage of time includes marketing and sales, project management, communication, administration, development of design and preliminary investigation.

5.2.2 <u>TIME DEVOTED TO INEFFICIENT ACTIVITIES</u>

The respondents were requested to indicate what percentage of their work could be performed just as effectively by persons with a lower qualification (Appendix III, Question 10B). If part of the activity performed by engineers could be done by personnel with a lower qualification it would mean that the engineer was devoting time to an inefficient activity i.e. the engineer was being under utilized or inefficiently utilized.

The extent of under utilization is indicated in table 17 below.

TABLE 17

PERCENTAGE OF WORKING TIME SPENT ON A FUNCTION THAT COULD BE PERFORMED BY A PERSON WITH A LOWER-QUALIFICATION

JOB FUNCTION	PROFESSIONAL ENGINEER	GRADUATE ENGINEER	TECHNOLOGIST
	N=351	N = 199	N = 52
	X	X	X
1. PRELIMINARY INVESTIGATION	31.2	15.9	14.1
2. DEVELOPMENT OF DESIGN	35.2	18.5	15.3
3. DETAIL DESIGN DOCUMENTATION	41.6	23.3	15.0
4. COMMUNICATION	49.0	32.6	14.0
5. MEASURING AND ESTIMATING	52.3	36.8	15.2
6. INVESTIGATION AND EVALUATION	57.8	33.4	11.2
7. PROJECT MANAGEMENT	69.2	56.6	15.8
8. MAINTENANCE	62.7	49.7	15.2
9. MANAGEMENT	34.2	12.5	22.0
10. ADMINISTRATION	57.6	30.4	11.4
11. MARKETING SALES	59.1	54.2	23.0
12. EDUCATION AND TRAINING	53.8	12.6	7.7

In the case of professional engineers it is significant to note that under utilization or inefficient utilization varies according to activity from a minimum of 31 percent to a maximum of 69,2 percent.

Amongst the activities or job functions which stand out as tasks in which a considerable amount of work can be done by personnel with a lower qualification are:

- measuring and estimating
- maintenance
- administration
- project management and
- detail design documentation.

There is of course an interrelationship between the percentage of the work that can be performed by less qualified personnel and the percentage of time devoted to a job function or activity. Table 16 indicates that 11 percent of the working time of professional engineers is devoted to "project management". However, table 17 indicates that 69,2 percent of the time professional engineers devote to "project management" could be saved by having less qualified persons perform these activities. It thus means that roughly 7,6 percent of the working time devoted to project management by professional engineers could be saved since the activities could be performed by personnel with a lower qualification.

5.2.3 **ACTUAL TIME DEVOTED TO EACH ACTIVITY PER ANNUM**

The product of number of weeks worked per annum and the number of hours worked per week reflects the actual number of hours worked per annum.

Table 18 indicates the average duration of the working year, the number of hours worked per week and the number of weeks worked per year.

TABLE 18

HOURS WORKED PER ANNUM

OCCUPATION	WEEKS WORKED PER ANNUM		HOURS WORKED PER WEEK		ACTUAL HOURS WORKED PER ANNUM	
	N	AVERAGE WEEKS	N	AVERAGE HOURS	N	AVERAGE HOURS
PROFESSIONAL ENGINEER	351	48	351	47,2	351	2265,6
GRADUATE ENGINEER	186	48	186	44,0	186	2112,0
TECHNOLOGIST	52	48	52	44,0	52	2112,0

5.2.4 **TOTAL SAVING OF TIME AND MANPOWER**

The total saving of time, which could be incurred if a less qualified person performs activities normally performed by mechanical engineers, is calculated in accordance with the formula developed in section 3.5.3 of this document.

Essentially the saving of time is the product of the following three terms:

- actual hours worked per annum
- percentage time devoted to a specific activity or job function and
- percentage time of the specific function above, that a less qualified person could perform.

Table 19 indicates the saving of time and manpower which could be achieved by employing less qualified persons to perform a portion of activities currently performed by mechanical engineers.

TABLE 19

ANNUAL MANPOWER SAVINGS

ACTIVITY	ANNUAL SAVINGS				TOTAL SAVINGS PER ACTIVITY
	PROFESSIONAL ENGINEERS		GRADUATE ENGINEERS		
	HOURS PER Pr Eng	MAN YEARS	HOURS PER Grad Eng	MAN YEARS	MAN YEARS
1. Preliminary Investigations	56,5	8,8	26,9	2,5	11,3
2. Development of Design	63,8	9,9	46,8	4,4	14,3
3. Detail Design Documentation	37,7	5,8	34,5	3,2	9,0
4. Communications	100,1	15,5	68,9	6,5	22,0
5. Measurement and Estimating	35,5	5,5	31,1	2,9	8,4
6. Investigation and Evaluation	52,4	8,1	28,2	2,7	10,8
7. Project Management	172,4	26,7	119,5	11,3	38,0
8. Maintenance	71,0	11,0	63,0	5,9	16,9
9. Management	178,1	27,6	34,2	3,2	30,8
10. Administration	104,4	16,2	45,0	4,2	20,4
11. Marketing, Promotion and Sales	66,9	10,4	5,0	5,4	15,8
12. Education and Training	73,2	11,3	18,6	1,8	13,1
	TOTAL MAN YEARS SAVED FOR ALL ACTIVITIES				* 210,8

* Expressed as a percentage, 210,8 man years represents a total savings of 38 percent of the 550 engineers (graduates and professionals) who participated in the survey.

The mathematical basis for Table 19 is developed comprehensively in Appendix VII.

Since one man year is equal to one mechanical engineer it is thus apparent that about 210 mechanical engineers could be "saved" by employing less qualified persons to perform a portion of the activities which currently mechanical engineers perform.

A saving of 210 mechanical engineers compared to the total of 550 professional and graduate engineers who participated in this study means a savings of 38 percent. Alternatively, the mechanical engineer's utilization could be increased by as much as 38 percent thus resulting in a saving of 210,8 engineers.

If, however, one hypothetically assumes that the utilization of all 3500 mechanical engineers registered with SAI Mech E could be improved by 38 percent, then this would bring about a total saving of 1330 mechanical engineers which would result in a surplus since the shortage of mechanical engineers in 1987 was determined to be 178[40].

It would be unrealistic to expect an improvement in utilization of 38 percent in the short term. If it is assumed that an improvement in utilization of 10 percent is attainable in over the short term then almost immediately an additional 133 mechanical engineers would be available in South Africa. The number of 133 additional engineers is based on an improved utilization of 10 percent and a total population of 3500 mechanical engineers registered with SAI Mech E. The number of 133 engineers represents a decrease of almost 75 percent in the shortage of mechanical engineers.

It can thus be appreciated that marginal improvements in utilization of engineers have significant effects on reducing the shortage of mechanical engineers.

5.3 FACTORS CAUSING POOR UTILIZATION

Respondents were asked to indicate, for each activity, the extent to which five preselected factors contributed to under utilization. The factors were:

(a) no suitable personnel available in one organisation

(b) not enough suitable personnel available in the organisation

(c) impractical for another person to do part of the job

(d) person who could do the job cannot be kept fully occupied in the organisation

(e) bad management.

Respondents indicated on a five point scale (1 = none and 5 = very much) the extent to which each factor contributed to poor utilization of mechanical engineers.

The results presented in table 20 indicates the extent to which each factor (a to e) contributes to the under utilization of mechanical engineers.

Factors (a) and (b) point towards a lack or shortage on the supply side. Factor (b) "not enough suitable personnel available in the organization" was given the as the most important reason contributing towards the current situation which results in inefficient utilization of mechanical engineers. This applied to all job functions or activities except "management" where factor (c) "impractical for another person to do part of the job" was ranked higher.

Table 20 further indicates that factors (c) and (d) generally play an important role in contributing to under utilization, however, very little can be done about these factors.

Finally it is apparent, judging by the low rating given to (e), that respondents are of the opinion that "bad management" played a minor role in contributing to poor utilization of mechanical engineers.

TABLE 20

CONTRIBUTION OF VARIOUS FACTORS TO POOR UTILIZATION

JOB FUNCTION	FACTOR	PROFESSIONAL AND GRADUATE ENGINEERS	
		N	X
1. PRELIMINARY INVESTIGATION	a	58	3.5
	b	90	4.4
	c	48	3.2
	d	18	2.5
	e	7	2.0
2. DEVELOPMENT AND DESIGN	a	49	3.6
	b	87	4.2
	c	40	3.0
	d	18	2.6
	e	6	2.4
3. DETAIL DESIGN DOCUMENTATION	a	32	3.2
	b	70	4.8
	c	28	3.0
	d	26	3.1
	e	3	1.7
4. COMMUNICATIONS	a	45	3.8
	b	81	3.5
	c	80	4.0
	d	31	3.4
	e	16	3.5
5. MEASUREMENT AND ESTIMATING	a	39	3.4
	b	75	4.3
	c	40	3.7
	d	30	3.2
	e	5	2.0
6. INVESTIGATION AND EVALUATION	a	37	3.8
	b	92	4.3
	c	41	3.9
	d	20	1.7
	e	4	2.0
7. PROJECT MANAGEMENT	a	47	4.0
	b	110	4.7
	c	48	3.8
	d	29	3.2
	e	13	2.8
8. MAINTENANCE	a	39	4.2
	b	61	3.8
	c	27	2.6
	d	21	3.1
	e	13	2.2
9. MANAGEMENT	a	56	3.8
	b	51	3.4
	c	71	4.6
	d	20	2.2
	e	14	1.7
10. ADMINISTRATION	a	58	3.6
	b	76	3.8
	c	70	3.7
	d	52	3.2
	e	34	3.0
11. MARKETING, PROMOTION AND SALES	a	21	4.0
	b	35	3.8
	c	23	3.4
	d	16	2.2
	e	9	1.0
12. EDUCATION AND TRAINING	a	30	3.9
	b	39	4.2
	c	27	3.4
	d	13	2.0
	e	10	1.8

X = VALUE OF CONTRIBUTION ON A SCALE OF 1 to 5

5.4 TRAINING REQUIREMENTS OF A MECHANICAL TECHNICIAN

Table 21 indicates the most appropriate level of academic qualification required by personnel who could support the mechanical engineer in the execution of his duties. From table 21 it is suggested that the education qualification required by the mechanical technician is that of group 4 i.e. either a National or National higher Diploma. Respondents further indicated that the bias of the required qualification should be technical as opposed to administrative.

In the case of the job function or activity "Administration", respondents indicated that the support staff required an elementary education i.e. Std 10. This is indicative of the fact that many of the administration activities performed by mechanical engineers are way below his or her level of academic training. This could possibly be one of the areas of greatest inefficiency.

TABLE 21

ACADEMIC REQUIREMENTS OF SUPPORT PERSONNEL

JOB FUNCTION	TRAINING BIAS	QUALIFICATION *					
		1	2	3	4	5	6
1. PRELIMINARY INVESTIGATION	Admin.	3	2	6	9	3	0
	Technical	4	13	38	102	61	9
2. DEVELOPMENT OF DESIGN	Admin.	0	0	0	1	0	0
	Technical	1	6	3	116	60	8
3. DETAIL DESIGN DOCUMENTATION	Admin.	1	0	1	1	1	0
	Technical	2	7	36	1091	2	3
4. COMMUNICATIONS	Admin.	14	14	27	19	7	1
	Technical	4	13	45	88	31	1
5. MEASUREMENT AND ESTIMATING	Admin.	6	4	9	7	4	0
	Technical	4	14	69	59	13	1
6. INVESTIGATION AND EVALUATION	Admin.	5	2	5	2	0	0
	Technical	1	8	46	96	28	4
7. PROJECT MANAGEMENT	Admin.	5	8	14	16	10	0
8. MAINTENANCE	Admin.	5	3	5	9	1	0
9. MANAGEMENT	Admin.	16	7	15	40	35	3
10. ADMINISTRATION	Admin.	73	37	52	45	19	2
11. MARKETING, PROMOTION AND SALES	Admin.	2	9	10	18	8	2
	Technical	4	4	9	18	17	2
12. EDUCATION AND SALES	Admin.	0	3	5	11	0	1
	Technical	2	1	19	43	36	11

* For qualification types refer to table 11 on page 67.

CHAPTER 6

DISCUSSION

6.1 INTRODUCTION

The results of this study conclusively indicate that mechanical engineers are being ineffectively utilized. This ineffective utilization has wide ranging implications for:

- industry and the government who are both users of this specific type of manpower, and
- universities and technikons who are the suppliers of mechanical engineers and mechanical engineering technicians respectively.

The implications, of ineffective utilization of mechanical engineers, for industry, government, universities and technikons will be comprehensively examined in this chapter.

The study furthermore indicates that there is a shortage of mechanical engineers in South Africa at this time and that the shortage is both real and artificial. It is real in the sense that the national demand for mechanical engineers exceeds the numbers available. The shortage is to some extent artificial in that the efficiency of the use of mechanical engineers is only 62 percent i.e. 38 percent of the output of each mechanical engineer is wasted.

In order to facilitate an improvement in the utilization of mechanical engineers and in so doing to reduce the shortage of mechanical engineers it is of paramount importance that managers of industrial and commercial concerns should have an in-depth knowledge of factors affecting utilization. Since mechanical engineering manpower may be regarded as an input cost in most industrial concerns it is in the pursuance of profit maximization or cost minimization that employers should seek to maximize the utilization of mechanical engineers as well as all other types of manpower employed.

6.2 UTILIZATION IN PRACTICE

This study, which amongst other things analysed the functions performed by mechanical engineers, found that as much as 38 percent of the engineer's time is spent on activities which do not require the unique training of a mechanical engineer. Fundamentally, this finding means that in practice or in industry mechanical engineers are performing tasks which could be performed by less qualified personnel such as technicians.

The figure of 38 percent obtained in this study compares well with the value of 30 percent inefficient utilization obtained by Terblanche(41).

Initially, the comparison of the 38 percent inefficient utilization obtained by this study with the value of 64,2 percent inefficiency obtained by Hirsch(42), et al, proved somewhat disappointing. However, careful scrutiny of the Hirsch study revealed that factors other than "time spent on activities which do not employ the unique training of engineers" were taken into account when they determined the percentage inefficient utilization. It would thus be somewhat unrealistic to expect a close correlation between the results obtained by this study and those obtained by Hirsch, et al.

However, based on answers to question 35 of the questionnaire Hirsch(43), et al, used in their survey, the average engineer indicated that his or her capabilities are not used for 35 percent of the time i.e. that their inefficiency was 35 percent. This value correlates very well with both the values of 38 percent and 30 percent obtained by this study and Terblanche respectively.

The results, in respect of inefficient utilization, obtained by both this study and Terblanche are based on a utilization model which uses as a basic input, information or data supplied by the engineers themselves. Hence an element of subjectivity may well be present in the results obtained from such models. Furthermore these models do not consider any additional factors as in the case of Hirsch[44], et al, who pointed out that whilst much of the work performed by an engineer may not be below his engineering training or capability i.e. may be efficient work, it might still be classed as unproductive work.

These additional factors which Hirsch, et al, considered to contribute to inefficiency of utilization are:

- assignments of little or no value;
- time spent on unassigned activities;
- duplication of effort;
- employee turnover, and
- physical facilities.

Subsequent discussions will clearly show that all of the above mentioned factors do, to varying degrees, influence the efficient utilization of engineers, and in practice these factor do result in decreased efficiency, however, the problem lies in trying to quantify the effect of each factor on the overall utilization.

(i) Assignments of little or no value

In this situation, engineers are used to their fullest capabilities in performing the work, but there is little or no reason for the assignment. It might be argued that as long as any creative work is being performed, it has value. While this is true, in this discussion it is assumed that the goal is to maximise utilization and in this regard all effort should be coordinated. Reasons for performing assignments of little value were given by Hirsch(45) to include:

- poor planning on the part of management or supervisors, and
- where engineers are maintained by companies in order to secure certain contracts.

(ii) Time spent on unassigned activities

This category concerns the time spent on inefficient activities such as:

- personal projects,
- relaxation and relief (tea and toilet breaks), and
- unnecessary reading.

It is not suggested that the engineer should be deprived of reasonable relaxation. A major concern in this category is the necessity to create in the individual engineer a feeling that he belongs to and is part of the organization. This concern is related to the problem of human motivation. Very little information on the interrelation between motivation and utilization was uncovered and this could certainly be suggested as an area for future research.

(iii) Duplication of effort

Duplication of effort is taken to refer to efforts being expended on the same activities when the duplication is unknown to the parties concerned. Such duplication of effort exists both between different companies and within individual companies. Reasons for such duplication may include:

- competitive restrictions between companies;
- poor communications, and
- organizational weaknesses within companies.

Hirsch[46], et al, estimates that the loss of engineering time due to duplication of effort may be anywhere between 30 and 50 percent.

(iv) Employee turnover

Hirsch[(47)], et al, contends that employee turnover is wasteful to engineering manpower utilization, primarily because of time which is spent by the engineer in becoming reoriented to the new environment. Time lost in reorientation varies greatly with the individual and the company, however, Hirsch's estimate is that job-changing could decrease an engineer's output by about 20 percent.

(v) Physical Facilities

It is a fact that utilization of engineers like almost all types of personnel is to some extent affected by the numerous aspects of physical environment. It is difficult to attempt to estimate the corresponding increase in utilization that may accompany a change in physical facilities or conditions, thus further research is certainly needed in this field. It appears quite likely that certain changes would cause significant increases in human output.

6.2.1 **OVER-ALL UTILIZATION**

All of the factors identified by Hirsch serves to further erode the engineer's efficiency, hence the efficiency of engineering utilization cannot be assumed to be that efficiency obtained by considering inefficient or nonproductive uses alone. The over-all efficiency is the product of the various individual efficiencies of the complete system.

The value of efficiency of 62 percent obtained in this study is thus considered to be a high side value. Taking cognisance of additional efficiencies would have the effect of further reducing the value of efficiency obtained in this study.

Future research on the subject of "utilization of engineering manpower" should endeavour to focus on a quantitative analysis of the factors mentioned here.

6.3 <u>CAUSES OF POOR UTILIZATION</u>

Based on the quantitative analysis of the utilization of mechanical engineers conducted by this study, it seems reasonable to assume that the utilization of 62 percent is lower than could be realized under "optimum conditions". Consideration was given to the possible causes for the present conditions not being optimum.

The study essentially focused on the relative importance of five factors which were identified by a previous study[48] to contribute to poor utilization. The results contained in table 20 clearly indicate that the major cause for poor utilization of mechanical engineers is a lack of sufficient, suitably trained support staff to assist the engineer.

It is interesting to note that respondents felt that management did not play an important role in contributing towards inefficient utilization. However, management should take cognisance of the benefits which result from improved utilization and endeavour to ensure that the highest possible utilization of its engineering manpower is being attained. The finding of this study with regards to causes of poor utilization correlates well with the results of the study conducted by Cilliers[49] on the possible causes for poor utilization of electrical and electronic engineers. Cilliers is of the opinion that the provision of sufficient suitably qualified technicians will to a large extent reduce the shortage of engineers.

The finding of this study is supported by Davidson[50] who cited an example of a large American company which found that it could reduce its engineering staff by 15 percent, get more work done by happier engineers and pay them better, by relieving them of non-technical duties. The hiring of a few more clerks, secretaries and engineering technicians did the trick!

In support of the above finding Professor G Bozzoli[51] wrote:

> "The inefficient utilization of highly trained manpower is not solved by inducing more young men to take university degrees in engineering, since this will only result in greater inefficiency".
> "Clearly, the answer lies in training many, many more young men and women as technicians".

6.4 SUPPORT PERSONNEL FOR MECHANICAL ENGINEERS

This research study along with various others[4][10] have clearly indicated that the engineer's performance and utilization would be enhanced by employing supporting personnel who could undertake a host of routine activities identified by Hirsch[20], et al.

It is recognised that it is both impractical and undesirable to relieve the engineer of all the routine activities, however, it is the contention of the researcher that care must be taken to prevent these activities from absorbing a substantial portion of his time.

The extent to which an engineer would require the services of either a technical or administrative assistant would depend on the nature of his work and also on his experience and the nature of his responsibilities. By referring to figure 7 it can be shown that a typical mechanical engineer's career can be roughly divided into three phases:

(i) The first 5 years after graduation:
this period is generally dominated by technical tasks with limited managerial functions.

(ii) The next 5 to 10 years:
during this period management activities rapidly increase in importance while theoretical or technical tasks decrease.

(iii) The last phase of the mechanical engineer's career:
this period is dominated by managerial activities which occupy more than 60 percent of his time.

The above information has implications for the training of both engineers and technicians and these will be examined later in section 6.6.

Admittedly, this is a very simplified picture of an engineer's career, however, it is useful in determining the training bias required of support personnel at various stages in the engineer's career.

Table 21 reflects that most respondents indicated that technical assistance would serve the engineer better than administrative support. However, the information contained in table 21 bears no reference to the engineer's experience or the phase of his career in which he is. Hence, while the data in table 21 is statistically correct it does not have much value unless it is considered along with additional information about the engineer's experience.

Smit[52] contends that the type of assistance required by an engineer is directly related to the nature of tasks he is performing. Based on the aforementioned contention it would be correct to deduce that the average mechanical engineer would require the following type of assistance during the various phases of his career:

First phase : technical

Second phase : a combination of technical and managerial

Third phase : managerial

Respondents indicated that the desired level of academic qualification of the technical support personnel should be a National Diploma (T3). No scientific basis exists to support or refute the claims made by respondents in the above regard. Possibly the information was based on experience.

6.5 CHANGING WORK PATTERNS WITH INCREASING EXPERIENCE

The results of the study as contained in table 15 indicates that a typical professional mechanical engineer would spend his working time roughly as indicated below:

Activity	% time
Theoretical Engineering	26
Practical Engineering	20
Management	54

The results contained in table 15 represents a "snapshot" of how mechanical engineers (professional and graduates) divide their time amongst theoretical engineering, practical engineering and management activities.

The data supplied by respondents enabled the variation in work patterns with increasing experience to be established.
The zero base of experience was set at age 25 years old and the results of the analysis are reflected in table 22 and figure 7 below.

TABLE 22

VARIATION IN TIME SPENT ON ACTIVITIES

WITH INCREASING EXPERIENCE

ACTIVITIES	YEARS OF EXPERIENCE				
	0	10	20	30	40
THEORY	62	38	28	26	26
PRACTICAL	11	12	10	10	12
MANAGEMENT	27	50	62	64	62
	100%	100%	100%	100%	100%

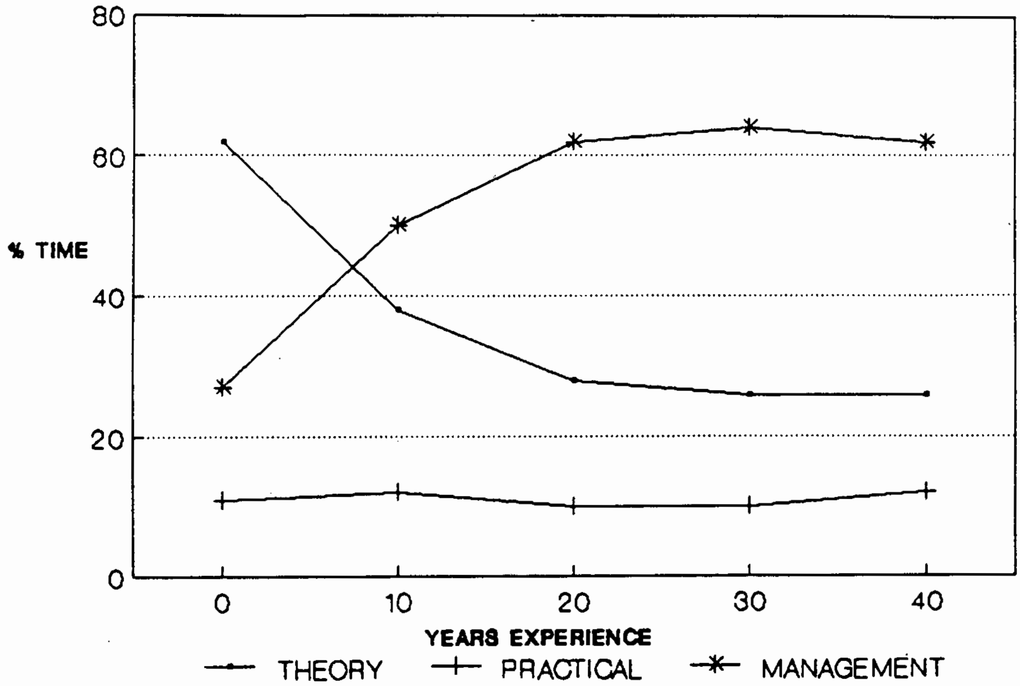


FIGURE 7

VARIATION IN TIME SPENT ON ACTIVITIES
WITH INCREASING EXPERIENCE

Theoretical functions decrease significantly from 62 percent at the beginning of the mechanical engineer's career to 26 percent after 40 years experience. However, managerial activities increase relatively rapidly where, after 10 years experience, management related activities occupy a typical mechanical engineer for 50 percent of the time. Management activities peak after 30 years experience and take up 64 percent of the engineer's time.

Practical engineering activities remain relatively constant throughout the mechanical engineer's career, fluctuating between 10 and 12 percent.

It is interesting to note that university education, in respect of engineering, essentially concentrates on knowledge related to theoretical activities(48). However, since theoretical activities rapidly decreases in importance for the average mechanical engineer as he gains experience, it could be inferred that mechanical engineers make decreasing use of their formal engineering education.

If the aforementioned inference is correct, then there is reason for serious concern since one could then further deduce that the utilization of an engineer decreases in direct relation to the decrease in use of theoretical engineering knowledge.

The above hypothesis would, however, require to be confirmed and it is suggested that much benefit could be derived from a study which determined the variation in utilization throughout the career of a typical mechanical engineer.

6.6 ENGINEERING EDUCATION FOR IMPROVED UTILIZATION

Table 12 on page 69 indicate that despite the fact that all respondents are registered with SAI Mech E and as such may be referred to as "engineers", 20 percent do not possess the basic academic qualification of an engineer i.e. B.Sc(Eng) which is evaluated as four years post matric.

The above information serves to confirm the contention that certain activities normally performed by engineers do not require the comprehensive training of an engineer and may be efficiently performed by a person with less academic training such as a technician in possession of a National Diploma.

Furthermore, figure 7 indicates that the basic mechanical engineering degree course provides engineers with a theoretical education which far exceeds the normal demands made on an engineer throughout his career. However, it could also be deduced that in other areas, noticeably management skills, the degree training does not equip an engineer to fully handle the demands made on him.

The suppliers (universities and technikons) of engineering manpower (engineers and technicians) are confronted with two main issues:

(i) engineers frequently perform activities which are below their level of training, and

(ii) the theoretical training of an engineer more than adequately prepares him for the performance of theoretical engineering activities.

The results contained in table 20 indicate that the main reason for poor utilization of engineers is "not enough suitable personnel available".

Clearly then, to solve the issue regarding engineers performing activities below their training requires the training of greater numbers of technicians at technikons. However, in order to effect the proposed solution it is important that the career of a technician be projected as an attractive alternative to that of an engineer.

It is thus proposed that urgent attention be given to the following aspects which currently restrict the training of sufficient numbers of engineering technicians for industry in general:

(i) <u>The professional status of technicians</u>

The status of the technician requires to be enhanced by:

- delegating activities to the technician which will make full use of his training, and
- remunerating the technicians in line with the level of work performed and responsibility carried.

(ii) <u>Financial Provisions for training technicians</u>

The state should ensure that sufficient, suitably funded technikons are provided for training an increased number of technicians. In this regard the state has a responsibility to ensure that technikon facilities are suitably equipped, funded and utilized. In order to assist the state in determining the number of technikons and the level of funding required, it is suggested that an investigation be commissioned with the mandate to establish:

- the number of technicians ideally required annually,
- the number of technikons required to support the training of these technicians,

- the optimum level of funding required by technikons to provide the numbers of technicians required by industry, and
- the necessity of provide bursaries to student technicians.

Universities play an important role in providing engineering graduates who are able to satisfy the technological and other demands made by industry. However, it it suggested that a study should be made to determine the caliber of engineer that industry needs i.e. to determine industry's requirement with regards to training in such aspects as theoretical engineering, practical engineering and management.

It is then further suggested that based on the findings of the proposed study, universities should determine the extent to which their courses require to be modified to meet the requirements of industry.

The above proposals will result in an improvement in the utilization of mechanical engineers and given the high cost of ineffective utilization it would be well worth pursuing(53).

Technikons should ensure that the National Diploma programmes are sufficiently balanced to ensure that the technician can provide both the technical and manegerial support required by the engineer.

CHAPTER 7

CONCLUSIONS AND RECOMMENDATIONS

7.1 INTRODUCTION

This investigation into the utilization of mechanical engineering manpower in South Africa was regarded as a pilot study. The findings were intended to:

(i) stimulate further research into related problems, and

(ii) initiate the adoption of a programme of action which would bring about an improvement in the utilization of mechanical engineers and in so doing result in a decrease in the shortage of mechanical engineers.

A summary of the most important conclusions which can be drawn from this study will be presented and finally, a summary of recommendations will be given.

7.2 CONCLUSION

The aim of the study was to investigate the utilization of mechanical engineering manpower in South Africa.

In the light of the survey on documented research literature related to the utilization and supply/demand for mechanical engineers, it is possible to make the following conclusions:

(i) Scientific research literature on the utilization of mechanical engineering manpower is scarcely available.

(ii) The bulk of available documented research literature is of little benefit to the industrialist to increase the utilization of his engineers.

(iii) A shortage of mechanical engineers has most certainly existed in South Africa since a least 1973. Since then the shortage has tended to decrease from a level of about 275 mechanical engineers in 1973 to 178 in 1987.

The study used the model employed by the Federation of Societies of Professional Engineers to determine the shortage of mechanical engineers.

Models used to determine the utilization of mechanical engineers were reviewed and the study adopted a model which used the percentage of working time spent on different activities as a basis.

The study then set out to seek empirical data on:

(i) how mechanical engineers spend their working time, and

(ii) what percentage of working time mechanical engineers spend on activities which they consider to be below their training.

Based on the findings of this study it is possible to conclude that:

- mechanical engineers are certainly ineffectively utilized in South Africa and

- the extent of the ineffective utilization is of the order of 38 percent.

The study examined the sensitivity of the shortage of engineers to variations in utilization and in this regard it can be concluded that the shortage of mechanical engineers is very sensitive to variations in utilization i.e. the shortage will be greatly reduced by a small increase in utilization of mechanical engineers.

Empirical data was also obtained in respect of:

- the factors which cause poor utilization of mechanical engineers and

- the level of training required by personnel who could support the engineer in the performance of those activities considered to be below the engineers training or routine in nature.

In light of the findings of the study it can be conducted that:

- the factor which contributes the most to poor utilization of mechanical engineers is the shortage of adequately trained support staff or technicians, and
- finally, the study concluded that the most appropriate level of training for the support staff is that of a National Diploma i.e. a qualification evaluated as matric plus three years.

7.3 RECOMMENDATIONS

On the strength of the findings it is possible to make recommendation as to how the utilization of mechanical engineers may be improved and in so doing reduce the the shortage of mechanical engineers.

Since the problem of a shortage of mechanical engineers is a national one, it is recommended that it be addressed by a National committee comprising representatives from the South African Council for Professional Engineers, the Department of Manpower and the South African Institution of Mechanical Engineers. This committee should serve to coordinate the nation's effort to meet the growing demand for mechanical engineers by amongst other things:

(i) increasing public understanding of the importance of optimum utilization of engineers to South Africa's future,

(ii) encourage the training and the use of technicians to release engineers from routine duties,

(iii) gather more adequate data on supply and demand of engineering manpower,

(iv) making maximum effective use of our existing supply of engineers,

(v) promoting scientific and mathematics at primary and secondary schools in order to increase the number of people entering the engineering field, and

(vi) making companies aware of inefficiencies associated with:

- duplication of effort,
- poor working conditions, and
- high turnover.

It is recommended that universities ensure that the engineers they are producing fully meets the requirements of industry.

In the above regard it is recommended that universities review their academic programmes with the view to ensuring:

- a correct balance between technical and managerial training, and
- that the engineering course content is related to the functions that engineers actually perform in industry.

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APPENDIX I

IMMIGRATION

The method of determining the immigration of professionally qualified engineers is as follows:

a. Data are obtained from the Central Statistical Services on the immigration of all engineers in an even-numbered year.

b. Data are obtained from SACPE on the number of professional engineers whose first engineering degree was from overseas and who were registered in the same even-numbered year.

c. An estimate is made of the proportion of engineers in each discipline who are eligible to register and who do in fact register.

d. A first estimate is made of immigrant engineers (b/c)

e. The ratio (d/a) of estimated to actual immigrants is calculated.

f. The historical value of (d/a) is updated.

g. The updated value of (d/a) is used to estimate true immigration as (a*f).

The latest data is as follows:

	Mechanical Engineers
a.	19
b.	28
c.	.66
d.	42
e.	2.21
f.	.66
g.	13

The fact that b is greater than a is unusual - historically it has usually been found that b less than a and, for instance, b was always less than 0,1a for electrical engineers.

APPENDIX II

Mechanical Engineers

	Year						
	1977	1979	1981	1983	1985	1987	1987
Graduates	144	154	148	208	274	355	286
SACPE Pt III	0	0	3	1	9	1	5
Immigrants	101	27	55	82	43	42	65
Supply	245	181	206	291	326	396	356
Vacancies	211	420	454	331	316	178	327
Demand	456	601	660	622	642	576	683

QUESTIONNAIRE

UTILIZATION OF MECHANICAL ENGINEERS

1. Indicate which category describes your present position in your organization the best:

   Professional Engineering (Pr. Eng) ☐

   Graduate Engineer (In-Training) ☐

   Graduate Engineer ☐

   Technologist ☐

   Technician ☐

   Other (Specify) ☐

2. In which sector are you employed?

   Government Sector ☐

   Public Sector (Iscor, Escom, Armscor) ☐

   Private Sector ☐

3. Which category listed best describes the level at which you work in your organization.

   ☐ Top Management

   ☐ Middle Ma agement

   ☐ Industrial Management

   ☐ Other

4. Highest qualification you possess. Refer to code list overleaf and circle appropriate number. 6 5 4 3 2 1

5. Date of birth (year only) **19.** ☐

6. Average working time per week ☐ Hours

7. Average number of weeks devoted to work per year ☐ Weeks

8. Male ☐ Female ☐

9. What is your annual gross remuneration? Please ✓ appropriate box.

☐	☐	☐	☐	☐	☐
<20	20 - 25	26 - 30	31 - 35	36 - 40	>40

(RANDS x R1000)

Regent

JOB FUNCTION	A % of average working time spent on each job function	B % of time as indicated in A that a person with lesser qualifications could do.	C Required training of person mentioned in B. Indicate category by circling A or T A = Administrative T = Technical	D Qualification group of person mentioned in C. Indicate by circling the appropriate group.	E If you have indicated any % in column B indicate to what extent the factors listed below this column have contributed to this situation: See example below
1 Preliminary Investigation e.g. planning and feasibility studies, contract planning and programming			A T	1 2 3 4 5 6	a b c d e f
2 Development of Design e.g. original design, calculations, analysis, evaluation of alternative designs and conceptual or sketch drawings			A T	1 2 3 4 5 6	a b c d e f
3 Detail Design Documentation e.g. calculation (sizing) of components, preparation of final drawings and schedules			A T	1 2 3 4 5 6	a b c d e f
4 Communications e.g. reporting (verbal and written), written specifications, preparation of schedule of quantities			A T	1 2 3 4 5 6	a b c d e f
5 Measurement and Estimating e.g. measuring quantities, estimating and tender preparation			A T	1 2 3 4 5 6	a b c d e f
6 Investigation and Evaluation e.g. evaluation of materials and components against specifications, tender evaluation			A T	1 2 3 4 5 6	a b c d e f
7 Project Management e.g. procurement, construction and installation, contract supervision and commissioning of plant and machines			A T	1 2 3 4 5 6	a b c d e f
8 Maintenance e.g. planning programmes, implementation execution and evaluation			A T	1 2 3 4 5 6	a b c d e f
9 Management e.g. development of policy, co-ordinating, supervision of personnel, production			A T	1 2 3 4 5 6	a b c d e f
10 Administration e.g. completion of retuns, procedures			A T	1 2 3 4 5 6	a b c d e f
11 Marketing, Promotion and Sales			A T	1 2 3 4 5 6	a b c d e f
12 Education and Training (a) Giving training/lecturing (b) Receiving training (c) Research			A T	1 2 3 4 5 6	a b c d e f
13 Travel			A T	1 2 3 4 5 6	a b c d e f
14 Other			A T	1 2 3 4 5 6	a b c d e f
	100%				

GROUP	EDUCATIONAL QUALIFICATIONS
1	STD 10, (NTC III) NATIONAL TECHNICAL CERTIFICATE
2	NATIONAL TECHNICAL CERTIFICATE IV OR V (NTC IV, NTC V) ADVANCE TECHNICAL CERTIFICATE (ATC I & II) NATIONAL CERTIFICATE FOR TECHNICIANS NATIONAL HIGHER CERTIFICATE FOR TECHNICIANS (NCT) INTERMEDIATE DIPLOMA FOR TECHNICIANS (IDT)
3	NATIONAL TECHNICAL DIPLOMA (NTD) NATIONAL ENGINEERING DIPLOMA HIGHER NATIONAL CERTIFICATE FOR TECHNICIANS (IDT)
4	NATIONAL DIPLOMA FOR TECHNICIANS (NDT) HIGHER NATIONAL DIPLOMA FOR TECHNICIANS (HNDT) GOVERNMENT CERTIFICATE OF COMPETENCY NATIONAL DIPLOMA NATIONAL HIGHER DIPLOMA
5	BACHELORS DEGREE IN ENGINEERING MASTERS DIPLOMA IN TECHNOLOGY
6	POST GRADUATE QUALIFICATION

GENERAL COMMENT

FACTORS

(a) No suitable personnel available in organisation
(b) Not enough suitable personnel available in organisation.
(c) Impractical for another person to do part of job
(d) Person who could do the job cannot be kept fully occupied in the organisation.
(e) Bad management
(f) Other

NOTE: The extent of contribution is indicated on a scale of 1 to 5 where 1 = none and 5 = much

Place a number (1 to 5) below the factor you select.

EXAMPLE

a	b	c	d	e	f
				5	

Regent

QUESTIONNAIRE

UTILIZATION OF MECHANICAL ENGINEERS

CATEGORIES OF MECHANICAL ENGINEERING PERSONNEL	NUMBER OF MECHANICAL ENGINEERING PERSONNEL IN YOUR EMPLOY	ADDITIONAL NUMBER OF MECHANICAL ENGINEERING PERSONNEL WHICH YOU COULD EMPLOY IF THEY WERE IMMEDIATELY AVAILABLE	INDICATE BY CIRCLING A NUMBER (1 to 5) THE AVAILABILITY OF MECHANICAL ENG. MANPOWER. EASILY AVAILABLE ⟷ NOT AVAILABLE
PROFESSIONAL ENGINEER (PR. ENG.)			1 2 3 4 5
GRADUATE ENGINEER (IN-TRAINING)			1 2 3 4 5
GRADUATE ENGINEER			1 2 3 4 5
TECHNOLOGIST			1 2 3 4 5
TECHNICIAN			1 2 3 4 5
TECHNICIAN (IN-TRAINING)			1 2 3 4 5

CLASSIFICATION OF CATEGORIES

CATEGORIES	QUALIFICATION
TECHNICIAN	A technician should have technical education above NTC 3 such as the National Diploma (T3) or National Higher Diploma (T4) in Engineering.
TECHNOLOGIST	A technologist is distinguished from the technician in that he can operate in a broader field, has greater depth of knowledge and possesses a technical qualification such as the Master Diploma in Technology. (T5)
GRADUATE ENGINEER	Usually a B Sc (Eng)
GRADUATE ENGINEER (IN-TRAINING)	is in possession of at least a B Sc (Eng) and is registered with South African Council for Professional Engineers as an "Engineer in-training".
PROFESSIONAL ENGINEER	Usually in possession of a B Sc (Eng) or higher qualification and is registered with SACPE as a Professional Engineer (Pr. Eng).

Department of Mechanical Engineering

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Head of Department: Professor R K Penny

27 May 1988

Dear Sir

The department of Mechanical Engineering of the University of Cape Town is appealing to you for help.
We are not asking for funds - all we ask is a few minutes of your time.

It is to your advantage to be a member of a profession which strives towards excellence by ensuring the most effective utilization of manpower resources.

You can assist us to maintain - and to enhance the status of the Profession - by co-operating in the study into the utilization of mechanical engineering manpower.

We have enclosed a questionnaire which will not take more than fifteen minutes of your time to answer. We are sure that you will be willing to make a contribution to the profession by completing the questionnaire.

As an enclosure with this letter you will find a self-addressed stamped envelope for returning the completed questionnaire.

Thank you for the courtesy of your prompt assistance.

Very sincerely yours

The University of Cape Town rejects racism and racial segregation and strives to maintain a strong tradition of non-discrimination with regard to race, religion and gender in the constitution of its student body, in the selection and promotion of its staff and in its administration.

Appendix 6

```
Press any key to continue...
Structure for database: C:\DBASEIV\UF.DBF
Number of data records:       767
Date of last update   : 10/25/89
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Field	Field Name	Type	Width	Dec	Index
1	Q1	Character	1		N
2	Q2	Character	1		N
3	Q3	Character	1		N
4	Q4	Character	1		N
5	Q5	Character	2		N
6	Q6	Character	2		N
7	Q7	Character	2		N
8	Q8	Character	1		N
9	Q9	Character	1		N
10	Q101A	Character	2		N
11	Q101B	Character	2		N
12	Q101C	Character	1		N
13	Q101D	Character	1		N
14	Q101E1	Character	2		N
15	Q101E2	Character	2		N
16	Q102A	Character	2		N
17	Q102B	Character	2		N
18	Q102C	Character	1		N
19	Q102D	Character	1		N
20	Q102E1	Character	2		N
21	Q102E2	Character	2		N
22	Q103A	Character	2		N
23	Q103B	Character	2		N
24	Q103C	Character	1		N
25	Q103D	Character	1		N
26	Q103E1	Character	2		N
27	Q103E2	Character	2		N
28	Q104A	Character	2		N
29	Q104B	Character	2		N
30	Q104C	Character	1		N
31	Q104D	Character	1		N
32	Q104E1	Character	2		N
33	Q104E2	Character	2		N
34	Q105A	Character	2		N
35	Q105B	Character	2		N
36	Q105C	Character	1		N
37	Q105D	Character	1		N
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39	Q105E2	Character	2		N
40	Q106A	Character	2		N
41	Q106B	Character	2		N
42	Q106C	Character	1		N
43	Q106D	Character	1		N
44	Q106E1	Character	2		N
45	Q106E2	Character	2		N
46	Q107A	Character	2		N
47	Q107B	Character	2		N
48	Q107C	Character	1		N
49	Q107D	Character	1		N
50	Q107E1	Character	2		N
51	Q107E2	Character	2		N
52	Q108A	Character	2		N
53	Q108B	Character	2		N
54	Q108C	Character	1		N
55	Q108D	Character	1		N
56	Q108E1	Character	2		N
57	Q108E2	Character	2		N
58	Q109A	Character	2		N
59	Q109B	Character	2		N
60	Q109C	Character	1		N
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63	Q109E2	Character	2		N
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65	Q1010B	Character	2		N
66	Q1010C	Character	1		N
67	Q1010D	Character	1		N
68	Q1010E1	Character	2		N
69	Q1010E2	Character	2		N
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71	Q1011B	Character	2		N
72	Q1011C	Character	1		N
73	Q1011D	Character	1		N
74	Q1011E1	Character	2		N
75	Q1011E2	Character	2		N
76	Q1012A	Character	2		N
77	Q1012B	Character	2		N
78	Q1012C	Character	1		N
79	Q1012D	Character	1		N
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87	Q1013E2	Character	2		N
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89	Q1014B	Character	2		N
90	Q1014C	Character	1		N
91	Q1014D	Character	1		N
92	Q1014E1	Character	2		N
93	Q1014E2	Character	2		N
94	COMMENT	Memo	10		N

ANAL1.PRG*

THIS PROGRAM DETERMINES THE AVERAGE QUALIFICATION PER JOB FUNCTION (Q10) PER CATEGORY (Q1) PER SECTOR (Q2).

```
SET TALK OFF
USE OF
STOR SPAC(7) TO V
STOR 11 TO N
N=0
STOR 1 TO Q2N
Q2N=2
STOR 1 TO Q1N
Q1N=0
STOR 1 TO I
I=0
STOR 111 TO SM
SM=0
STOR "ABCDEF" TO CHOICE
STOR 111.11 TO CNT
CNT=0
STOR 111 TO CNTER
CNTER=0
DO WHILE Q2N<3
   Q2N=Q2N+1
   DO WHILE Q1N<6
      Q1N=Q1N+1
      SET PRINT ON
      ? "***Q1=","",Q1N,"***Q2=","",Q2N,"***"
      SET PRINT OFF
      N=0
      DO WHILE N<14
         N=N+1
         I=0
         V="Q10"+LTRIM(STR(N))+"E1"
         DO WHILE I<6
            I=I+1
            AVERAGE VAL(SUBSTR(&V,2,1)) FOR VAL(Q1)=(Q1N) .AND.
               VAL(Q2)=(Q2N) .AND. SUBSTR(&V,1,1)=SUBSTR(CHOICE,I,1)
               TO CNT
            COUNT FOR VAL(Q1)=Q1N .AND. VAL(Q2)=Q2N .AND.
               SUBSTR(&V,1,1)=SUBSTR(CHOICE,I,1) TO CNTER
            SET PRINT ON
            ? N,SUBSTR(CHOICE,I,1),"    ",CNT,"    ",CNTER
            SET PRINT OFF
            CNT=0
         ENDDO
      ENDDO
   ENDDO
ENDDO
CLOSE DATA
```

ANAL2.PRG*

THIS PROGRAM DETERMINES THE NUMBER OF RESPONDENTS PER JOB FUNCTION (Q10) PER CATEGORY (Q1), AS WELL AS THE SUM OF THE PERCENTAGES UNDER A AND B OF Q10.

```
SET TALK ON
USE OF
STOR SPAC(7) TO V
STOR 11 TO N
N=0
STOR 1 TO Q2N
Q2N=2
STOR 1 TO Q1N
Q1N=0
STOR 1 TO I
I=0
STOR 111 TO SM
SM=0
STOR "AB" TO CHOICE
STOR 111.11 TO CNT
CNT=0
STOR 111 TO CNTER
CNTER=0
DO WHILE Q2N<3
   Q2N=Q2N+1
   DO WHILE Q1N<6
      Q1N=Q1N+1
      SET PRINT ON
      ? "***Q1=","",Q1N,"***"
      SET PRINT OFF
      N=0
      DO WHILE N<14
         N=N+1
         I=0
         DO WHILE I<2
            I=I+1
            V="Q10"+LTRIM(STR(N))+SUBSTR(CHOICE,I,1)
            SUM VAL(&V) FOR VAL(Q1)=Q1N TO SM
            COUNT FOR VAL(Q1)=Q1N .AND. val(SUBSTR(&V,1,1))<>0 TO CNTER
            SET PRINT ON
            ? N,SUBSTR(CHOICE,I,1),"    ",SM,"    ",CNTER
            SET PRINT OFF
            CNT=0
         ENDDO
      ENDDO
   ENDDO
ENDDO
CLOSE DATA
```

APPENDIX VII

Annual Manpower Savings for Professional Engineers

Savings on activity "Preliminary Investigation".

- Average per cent of time spent on "preliminary investigations" is 8 per cent. (Table 16)

- Average per cent of time spent on "preliminary investigations" which could be performed by a person with a lower qualification is 31,2 percent. (Table 17)

- Average hours worked per annum by professional engineers is 2265,6 hours. (Table 18)

- Savings which could be incurred by releasing professional engineers of tasks below their training is

$$= \frac{8}{100} \times \frac{31,2}{100} \times 2265,6 = 56,5 \text{ hours per Pr Eng}$$

- Total savings for all respondents who are classified as professional Engineers is 56,5 x 351 = 19831,5 hours.

- Divide 19831,5 by 2265,6 to convert to man years = 8,8 man years saved.