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ENGINEERING PROFESSIONALS: CRUCIAL KEY TO DEVELOPMENT AND GROWTH IN SOUTH AFRICA

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Engineering Professionals: Crucial Key to Development and Growth in South Africa

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List of abbreviations

ABET	Adult Basic Education and Training
ASEE	American Society for Engineering Education
ASGISA	Accelerated and Shared Growth Initiative for South Africa
BSc (Eng)	Bachelor of Science in Engineering
BTech	Bachelor of Technology
CAETS	Council for Engineering and Technological Sciences
CEO	Chief Executive Officer
CERTAC	Certificated Engineers Accreditation Committee
CETA	Construction Seta
CFAT	Carnegie Foundation for the Advancement of Teaching
CHIETA	Chemical Industries Sector Education and Training Authority
CPD	Continuing Professional Development
CREE	Centre for Research in Engineering Education
DET	Department of Education and Training
DoE	Department of Education
EASA	Engineering Association of South Africa
ECSA	Engineering Council of South Africa
EPAC	Engineering Programme Accreditation Committee
ESETA	Energy Sector Education and Training Authority
ESGB	Engineering Standard Generating Body
ETQA	Education and Training Quality Assurance
EU	European Commission
FET	Further Education and Training
GDP	Gross Domestic Product
HEMIS	Higher Education Management Information System () of Department of Education
HEQC	Higher Education Quality Committee
HSRC	Human Sciences Research Council
IDC	Industrial Development Corporation
JIPSA	Joint Initiative for Priority of Scarce Skills Acquisition
JSE	Johannesburg Stock Exchange
LFS	Labour Force Survey
MERSETA	Manufucturing Engineering and Related Services Sector Education and Training Authority
MQA	Mining Qualifications Authority
NAAMSA	National Association of Automobile Manufacturers of South Africa
NACI	National Advisory Council on Innovation
ND	National Diploma
NQF	National Qualifications Framework
NSBE	National Society for Black Engineers
NSFAS	National Student Financial Aid Schem
NSI	National System of Innovation
OHS	October Household Survey
PROTEC	Programme for Technological Careers
QC	Quality Council
QEC	Qualifications and Examinations Committee
SAACE	South African Association of Consulting Engineers
SAAE	South African Academy of Engineeirng

SAICE	South African Institution for Civil Engineering
SAIChE	South African Institute of Chemical Engineers
SAIEE	South African Institute for Electrical Engineers
SAIMechE	South African Institute for Mechanical Engineering
SAILI	Science and Industrial Learnership Initiative
SAIRR	South African Institute of Race Relations
SAQA	South African Qualifications Authority
SASCO	South African Standard Classification of Occupations
SET	Science, Engineering and Technology
SETA	Sector Education and Training Authority
SET4WRG	SET4Women Reference Group
SOE	State Owned Enterprise
TETA	Transport Sector Education and Training Authority
TIMSS	Third International Mathematics and Science Study
TPAC	Technology Programme Accreditation Committee
UCT	University of Cape Town
UK	United Kingdom
USA	United States of America

CHAPTER 1

THE LABOUR MARKET AND PROFESSIONAL MILIEU FOR ENGINEERING PROFESSIONALS IN SOUTH AFRICA

1.1 INTRODUCTION

This monograph on the work and education of engineering professionals has been produced at a crucial juncture in the history of engineering in South Africa. The country is embarking on a massive and very expensive expansion in infrastructure partly in preparation for its hosting of the FIFA World cup in 2010 and then also in upgrading power stations, building roads, airports, harbours, improving other services at municipal level, construction of the Gautrain, and the boom in the construction industry. At the same time it is facing a shortage of engineering capacity, particularly in the public sector, that has been described as one of the worst capacity and scarce skills crises in years. As an indication of the dilemma, it can be noted that South Africa, which is to be sole host of the 2010 World Cup, has 473 engineers[1] per million citizens while Japan, which co-hosted the 2002 World Cup along with South Korea, has 3 306. Even compared to other upper-middle-income countries (developing countries), like Chile (1 460 engineers per million citizens) and Malaysia (1 843 engineers per million citizens), South Africa's engineering capacity is low (Lawless, 2005). There are many factors contributing to our situation, including the status and image of the engineering professions in relation to other more lucrative careers, the shortage of matriculants who meet the criteria to gain entrance to engineering degree programmes and the high quality of engineering education, as South Africa is one of the countries that has joined the Washington Accord, which recognises the substantial equivalency of accreditation systems to assess that the graduates of accredited programmes are prepared to practice engineering at the professional level (Jones 2006). The high quality of engineering education in this country, as was also indicated by Professor Beatrys Lacquet, first women dean at the engineering faculty of Wits[2] and Professor Kadar Asmal (previous South African Minister of Education),[3] ironically makes our graduates in great demand internationally.

These and many other facets of the engineering professions in South Africa come under the spotlight in this study which is one of a number of professional case studies that form part of the HSRC's research project on Professions and Professional Education in South Africa. Each study investigates the major current issues in the profession concerned and considers the ways in which they are

1 This figure includes engineers who are not registered

2 Meer werk as mense, sê ingenieurs se eerste vroue-dekaan *Rapport* 25.03.2007

3 South Africa's brain drain dilemma *BBC News* 19 April 2004

addressed in educational programmes. The monographs present syntheses of these issues for public and policy attention.

This study drew on the following sources of data: employment data from Quantec (2007), which includes the October Household Survey (OHS) for the period 1996-1999, and the September Labour Force Survey (LFS) for the period 2000-2005; vacancy data from Department of Labour for the period April 2004 to March 2007 - these data were obtained from all South African vacancies published weekly in the Business Times Careers section of the Sunday Times; and enrolment and graduation figures of engineering students from the annual databases (1996-2005) of the Higher Education Management Information System (HEMIS) of Department of Education.

It should be noted that there are three main types of engineering professionals in South Africa: engineers, engineering technologists and engineering technicians. A fourth designation of 'certificated engineer' refers to particular certificates that need to be held for specific roles in mining and industry and is not discussed here in further detail. The designation depends first of all on the tertiary qualification that has been attained. Engineers hold a four year BSc (Eng) or BEng/Ing from a university, technologists hold a BTech from a university of technology, and technicians hold a National Diploma from a university of technology. Throughout this paper the term 'engineering professional' will be taken to refer to this collective group while the term 'engineer' refers only to those holding the four year university degree.

The monograph begins with the broader international context and drivers of change for engineering professionals in the South African labour market. This is followed by an analysis of the current employment and employment trends of engineering professionals in the country. The professional milieu for engineering professionals in South Africa is subsequently discussed. Chapter 1 is concluded with a discussion on the demand for engineering professionals in the workforce, followed by a conclusion.

The educational context for engineering professionals is provided in Chapter 2 which starts with the drivers of change in the education of engineering professionals, followed by a discussion on secondary education, reasons for studying engineering, and the supply of engineering professionals from tertiary institutions. This is followed by a more in depth discussion of various engineering programmes; challenges for higher education institutions that offer engineering programmes; student access and mobility or articulation; engineering training by Further Education and training (FET) colleges, engineering training through learnerships and a conclusion.

Chapter 3 provides strategies to enhance women taking part in engineering; factors influencing women in choosing engineering as a career; barriers experienced by women in engineering in the labour market; graduations and employment of women in engineering and a concluding paragraph. The monograph is concluded with a discussion on the attainments, as well as the challenges still to be addressed in engineering employment in South Africa and possible interventions and recommendations in order to overcome some of these hurdles.

1.2 THE CONTEXT FOR ENGINEERING PROFESSIONALS IN THE SOUTH AFRICAN LABOUR MARKET

It is a world wide trend that the lack of engineering capacity is hampering development, as stated by Johan Pienaar, registration manager at ECSA;[4] Robbie Venter, CEO of Altron;[5] Hugh Williams, chief executive of the International Marine Constractors Association;[6] Sipho Nkosi, Chamber of Mines president and Exxaro CEO.[7] Japan is running out of engineers[8] and there is a shortage of engineering teachers in India.[9] The shortage of engineers in South Africa is specifically seen as one of the worst capacity and scarce skills crises in years, with local municipalities being hit the hardest (Lawless 2005). South Africa is currently in a period of extensive expansion in state expenditure, partly in preparation for its hosting of the FIFA World cup in 2010 and then also in upgrading power stations, improving other services at municipal level, construction of the Gautrain, and the boom in the construction industry. Given the new context of expanded expenditure, particularly in the public sector, there are key questions to investigate in terms of the demand and supply of engineering professionals. Putting infrastructure (roads, power supply, water supply, building construction, telecommunication networks, recreational and other assets) in place, requires the input of all engineering disciplines, but especially civil engineering skills.

In terms of the employment of and demand for engineering professionals in the South African labour market two significant drivers were identified over the last three decades (Steyn and Daniels 2003). The first driver was the reduction in agriculture and mining's share in the Gross Domestic Product (GDP), and the second driver was the relative changes within sectors with respect to labour productivity and capital intensity. There has been a reduction in the demand for agricultural and mining engineers and an increase in the demand for engineers with expertise in manufacturing and service-related technologies. Substitution shifts in employment took place, away from the traditional sectors such as agriculture and mining sectors to the manufacturing sector. Historically, the gold mining industry has been a significant employer of engineers, but employment levels have decreased substantially in recent years. The negative growth in agricultural engineering graduations is a concern in a country like South Africa where agricultural engineering can contribute to increased productivity to address food shortages and job creation (Berry 2006).

It was also indicated by Steyn and Daniels that there has been a gradual decrease in the percentage of engineering professionals in the total labour force between 1994 and 2001. This was in contrast with the expansion of the economy since the

4 SA's wide engineering gap *Fin24.com* 21.10.2007

5 Altron CEO Robbie Venter on the skills shortage in SA… *EE publishers* July 2008

6 Tackling the Offshore Skills Shortage *SPG Media Limited* 18.10.

7 SA produces more mining skill, but can't keep up with growth, poaching *Mining Weekly* 22.07.2008

8 Japan faces engineering shortage *The New York Times* 18 May 2008

9 The shortag of engineering teachers in India is much more worse than observers in the United States are aware, Indian academics report *EE Times* 17 December 2007

mid-1990s that should have led to an increase in engineering employment. However, since the data show employment rather than demand shifts, actual demand for engineering professionals could be masked by the impact of potentially significant emigration or changes in organisation of work, such as sub-contracting which would imply that an individual might not be recorded as an employed engineer, but as a self-employed manager of a firm that was engaged in engineering work (Steyn and Daniels 2003).

Conversely, over the period 1996 to 2005, there was an absolute employment gain in the number of engineers and technologists which represents double the average employment growth of 2.7 per cent for the total economy over a five year period.

It is, however, exceptionally difficult to come up with authoritative numbers or even estimates for skills shortages or demand for engineering professionals. The reasons are manifold: the quality of official statistics; double counting of especially engineering professionals in the Sector Skills Plans of Sector Education and Training Authorities in the face of infrastructure investment; absence of a comprehensive national register of qualified engineering professionals – it is not compulsory for engineering professionals to register with ECSA; the nature of the world-of-work for engineering professionals – they are easily absorbed in non-related industries; and unreliable emigration figures – engineering professionals maintain their registration status if registered, regardless of where they are working or what type of work they are doing and do not always indicate emigration because they leave the country to go an work on projects for only a duration of time.

Employment is usually used as an indicator of the demand for an occupation or skills. In the absence of regular and consistent survey data based on the needs of companies that use engineering skills, Labour Force Survey (LFS) statistics are used for the purpose of analysis of demand for employment. However, it is important to note that these data can only be used as a proxy for demand.

1.3 CURRENT EMPLOYMENT AND EMPLOYMENT TRENDS OF ENGINEERING PROFESSIONALS IN SOUTH AFRICA

This section examines the major characteristics of the employed engineering professionals. The following information is presented: The total employment of engineering professionals who hold an engineering degree (engineers and technologists) or an engineering diploma (technicians); the employment of engineering professionals across the economic sectors; engineering professionals working as managers; the ratios of engineers to technologists to technicians; the demographic profile of this group in terms of race, gender and age; and remuneration trends for engineering professionals.

The data we use is from the October Household Survey (OHS) of 1996 to 1999 and the Labour Force Survey (LFS) of 2000 to 2005 (Qauntec 2007). Both of these surveys are designed and administered by the South African government's national statistics agency, Statistics South Africa (StatsSA). The reason why data from two different data sources, the OHS and the LFS are used is because StatsSA terminated the OHS after 1999. The methodology of the two surveys could have differed slightly, such as in the sampling or the weighting of data. As a result of the transition from one survey dataset to another, some discontinuity may be expected between trends expressed in the OHS data from 1996 to 1999, and trends in expressed in the LFS data from 2000 to 2005.

Both the OHS and LFS surveys are based on samples of the national population. High annual fluctuations in the number counts is a product of small sample size and the process of weighting raw data obtained through a sample to approximate national parameters (Wilson, Woolard & Lee 2004).

In order to smooth out fluctuations in employment trends over the whole 1996 to 2005 period, it was decided to calculate an employment average per annum over a 10-year period (1996-2005); and calculate the averages for 2-year periods over the 1996 to 2005 period to get a smoother graphical trend line.

The fluctuations in data are particularly evident when national employment totals are disaggregated to another category, such as race or gender. In order to smooth effects of fluctuations when disaggregating data, an average was calculated for the period covered by each survey. Thus, for the OHS which ran for a period of four years from 1996 to 1999, an annual average employment was calculated. Similarly, for the six year period from 2000 to 2005, an average employment was calculated. It should be apparent that there is not an even split in the number of years of data between the period before the millennium and the second period post millennium. This is because it was considered more important to retain the integrity of each series of survey data (OHS 1996-1999 and LFS 2000-2005) rather than to group one year of LFS data with the OHS series to create an even five year split for each period.

1.3.1 Total employment of engineering professionals in South Africa

Employment data on engineering professionals show huge fluctuations between 1996 and 2005 (Quantec 2007). To address fluctuations an employment average per annum over a 10-year period (1996-2005) was thus calculated (Table 1.1 and 1.2). An employment average for 2-year periods over the 1996 to 2005 period was calculated to get a smoother graphical employment trend line (Figure 1.1).

Table 1.1 shows that on average 124 567 people were employed in engineering professional positions in South Africa over the 1996 to 2005 period. Almost a third (39 686) were employed as engineers and technologists and more than two-thirds (84 881) as technicians. Among those that were employed as engineers and technologists, on average, 60.98 per cent (24 202) had degrees, 16.79 per cent (6 667) National Diplomas and 22.21 per cent (8 817) only had a NQF4 or lower qualification. Among those employed as technicians, 3.58 per cent (3 047) had degrees, 27.91 per cent (23 694) had National Diplomas and more than two-thirds (58 140) had qualifications at NQF4 or less.

The large average number of 58 140 people who worked without the required qualification as engineering technicians is noteworthy. This trend relates to the difficulty that National Diploma students experience in finding industrial placements for their experiential training year (Interview 2006a; Lawless 2005). This means that they don't get the opportunity to work for an employer for the required period of time in order to complete their experiential training and obtain the necessary qualifications (Interview 2006a; Interview 2006b). Over the 1996-1999 period, 56.51 per cent of these underqualified engineering professionals were white and 47.86 per cent of them in the age category 65-69 years of age, while over the 2000-2005 period 45.19 per cent were white and younger than those in the earlier period with a quarter in the age category 30-34 years of age (Quantec 2007). Over the 1996-1999 period it could have been people that were appointed because of work experience already gained, although they did not have appropriate qualifications, as they were predominantly older people, while over the more recent period it is people that are younger and therefore probably those that are still trying to get experiential training in order to qualify.

Lawless (2005) found in her civil engineering study that about 60 per cent of final-year National Diploma students who responded to her survey in October and November 2004 had not had experiential training and therefore could not graduate. According to the LFS data it seems as if they are indeed working in the engineering labour market. At this level the skills are available, but strategies need to be put in place to assist the workers to complete the experiential training that will allow them to obtain their National Diplomas and register as professional engineering technicians. In this case it is necessary to distinguish between a *scarce skill* and a *skill gap* – these people are almost qualified and working as technicians, but they just need the opportunities to do their experiential training in order to close the *skill gap*.

The LFS data further reveal that about 10 000 people with a degree and over 48 000 people with a National Diploma in an ‘engineering-related field’ work in occupational categories ranging from sales workers to machine operators, except for managers. Furthermore, about 1 600 people with a degree in an ‘engineering-related field’ were unemployed, compared to over 10 000 with a diploma in an engineering-related field. Three-quarters (75.43 per cent) of this unemployed group were black (i.e. African, coloured or Indian), and well over half (59.08 per cent) were men. Although unemployment refers to those who are unemployed with an ‘engineering related field’ of qualification (which also includes fields of study such as manufacturing and technology and not only pure engineering, as unemployed in the OHS and LFS datasets cannot be identified according pure fields of study), it would be worth the while to explore and research this unemployment further to get a notion of the reasons for unemployment of these people with an ‘engineering related’ qualification.

Table 1.1 Total employment of engineering professionals according to occupation and qualification level, 1996-2005

Employed as Engineers & Technologists	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	Total	Average employed p.a.	% Average annual growth
Degrees	19890	15729	24153	19024	22212	28272	33868	23343	22181	33346	242018	24202	5.91
National Diplomas	167	10146	16977	6580	7343	2813	2862	2224	5818	11743	66672	6667	60.41
NQF4 or less	9471	12186	9523	13714	10730	2671	4309	4338	5121	16104	88167	8817	6.08
Total	29528	38061	50653	39318	40285	33756	41039	29905	33120	61193	396858	39686	8.43

Employed as Technicians	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	Total	Average employed p.a.	% Average annual growth
Degrees	2257	3089	1902	3016	1107	1723	2717	5810	2052	6798	30471	3047	13.03
National Diplomas	26405	8875	13330	16236	29362	22848	30470	24750	27222	37438	236935	23694	3.96
NQF4 or less	71684	10292	6958	68212	52174	63623	61903	68362	100549	77646	581404	58140	0.89
Total	100346	22256	22190	87464	82644	88194	95090	98922	129822	121881	848810	84881	2.18

Total employed as engineering professionals	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	Total	Average employed p.a.	% Average annual growth
Total	129874	60317	72843	126782	122929	121950	136129	128827	162942	183074	1245668	124567	3.89

Source: Quantec 2007

It is important to note that among those who were employed as engineers and technologist, a significant number (an average of 6 667 per annum) only had a national diploma level qualification. This could be as a result of poor data, coding problems, incorrect responses or because an insufficient number of qualified engineers and/or technologists are available to be appointed, especially at municipal level. According to Gareth van Onselen, Democratic Alliance's head of research in Parliament, South Africa's six major metropoles have 732 civil engineering professionals between them – not all qualified engineers- serving a population of about 15,6-million.[10]

For the purposes of the rest of this study we have decided to include all national diploma qualified people with the technicians and not with the engineers and technologists. Technicians with degrees were kept as technicians. Further analysis in this monograph will be based on the 24 202 annual average number of engineers and technologist with degrees and the 33 408 annual average number of technicians with national diplomas (23 694 plus 6 667) and degrees (3 047) employed over the 1996 to 2005 period.

Looking at the average number of engineers and technologists with degrees working in a specific year over the 1996–2005 period (Table 1.2), people with civil engineering degrees represent almost a third (29.30 per cent), mechanical engineers a fifth (20.25 per cent), and electrical engineers 15.97 per cent. The category 'engineers not elsewhere classified' (n.e.c.) represents about 14.64 per cent of total employment of engineers and technologists with degrees and includes engineering fields such as agricultural, industrial and robotics engineering according to the South African Standard Classification of Occupations (SASCO). Electronics and telecommunications engineers and technologists account for 6.35 per cent, while cartographers and surveyors, mining engineers, chemical engineers, metallurgists and related professionals represent about 4.85 per cent.

Considering the annual average number of technicians with National Diplomas/degrees over the same period, the picture looks different. Almost a third (30.91 per cent) held diplomas in electronics and telecommunications engineering, with electrical engineering technicians accountable for less than a fifth (17.53 per cent), mechanical engineering technicians 16.74 per cent and civil engineering technicians only 13.62 per cent. This trend impacts on the ratios of engineers and technologists to technicians in the different fields. It is especially in civil engineering where there is a shortage of enough technicians in proportion to civil engineers which impacts on service delivery at municipal level.

Among the degree-qualified engineers and technologists, the number of electrical engineers and technologists achieved an encouraging average annual growth rate of 36.39 per cent, cartographers and surveyors 16.84 per cent, those not elsewhere classified 12.60 per cent, and mechanical engineers and technologists 4.49 per cent over the 1996 to 2005 period. Negative growth rates are reported for the categories mining, metallurgist and related professionals (–13.64 per cent), chemical (–1 per cent), electronics and telecommunications (–0.38 per cent) and civil engineers and technologists (–0.18 per cent) over this period.

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10 Engineering a response to SA's infrastructure woes *Business Day* 5.03.2007

Contrary to the negative growth in employment for electronics and telecommunications engineers and technologists, there is an average annual increase of 13.23 per cent in employment for technicians in this field. The reverse is noticed for the electrical field: there is a slow growth in employment for electrical technicians compared to the very positive growth for electrical engineers and technologists.

For engineers and technologists the electrical engineering field shows the biggest absolute employment gain over the 1996–2005 period, while for technicians the most growth is in the field of mechanical engineering.

Table 1.2 Total employment of engineering professionals with degrees and national diplomas according to descipline, 1996-2005

Engineers & Technologists with degrees	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	Total	Average employed p.a.	% Average annual growth
Civil	12065	4115	7104	5264	3333	9663	6616	5760	5133	11870	70923	7092	-0.18
Electrical	523	3942	3038	1495	2218	5545	3939	3618	5790	8540	38649	3865	36.39
Electronics & telecom	1804	2211	0	794	5416	470	2911	1756	0	0	15361	1536	-0.38a
Mechanical	1992	556	7389	5026	4522	7446	10327	3608	5172	2959	48997	4900	4.49
Chemical	520	616	1412	1048	383	969	1736	2269	1074	475	10502	1050	-1.00
Mining & metallurgy	0	679	0	890	2871	801	1914	1980	1058	210	10403	1040	-13.64b
Cartographers & surveyors	527	1309	1983	249	1597	0	909	659	2375	2139	11748	1175	16.84
Not elsewhere classified (N.e.c.)	2459	2301	3226	4258	1872	3378	5516	3693	1579	7153	35436	3544	12.60
Total with degrees	**19890**	**15729**	**24153**	**19024**	**22212**	**28272**	**33868**	**23343**	**22181**	**33346**	**242018**	**24202**	**5.91**

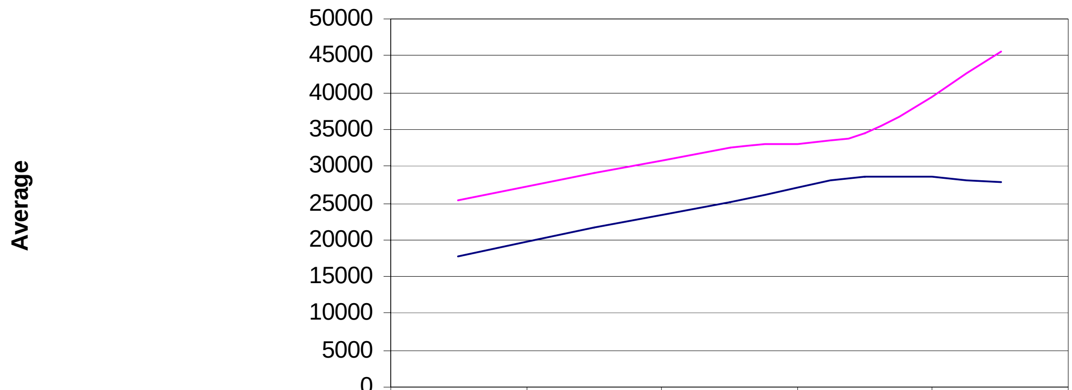
Technicians with National Diplomas or degrees	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	Total	Average employed p.a.	% Average annual growth
Civil	6279	6300	5994	1182	7682	4321	3816	1758	1628	6543	45504	4550	0.46
Electrical	7529	3420	7749	4124	4052	3565	8868	4155	6319	8772	58552	5855	1.71
Electronics & telecom	7796	2389	5741	6530	8079	8376	9502	16290	14714	23848	103266	10327	13.23
Mechanical	2124	3286	6212	6688	10411	4106	7131	2023	2420	11507	55909	5591	20.65
Chemical	0	0	583	1794	0	676	1943	0	395	0	5391	539	-6.27c
Acidiser	2339	924	539	0	1232	1291	1339	1030	2958	2470	14121	1412	0.61
Draughtsperson	1449	1968	2798	2180	3795	4279	2950	6825	5289	2562	34093	3409	6.54
Not elsewhere classified (N.e.c.)	1313	3823	2591	3333	2562	772	500	705	1367	277	17243	1724	-15.87
Total with ND/degree	28829	22110	32208	25831	37813	27384	36049	32784	35091	55978	334078	33408	7.65

Note: [a]1996-2003; [b]1997-2005; [c]1998-2004
Source: Quantec 2007

Figure 1.1 provides a picture of the employment trends for engineers, technologists and technicians over the 2-year periods (based on figures in Table 1.2). The figures show that the average annual growth rate of employment for engineers and technologists for the full period 1996-2005 was 5.91 per cent. Technicians formed the same trend as the engineers and technologists over the 96/97 to 02/03 period; however, over the 04/05 period there has been a drastic increase in the number of technicians as opposed to the decrease in the number of engineers. The average annual growth in the number of technicians over the whole 1996 to 2005 period was 7.54 per cent (from 28 829 in 1996 to 55 978 in 2005).

Table 2.2 (see supply of engineering professionals) will show there was also a bigger increase in the graduations of technicians at tertiary institutions (2.50 per cent average annual growth) than in the graduations of engineers (1 per cent average annual growth) over the 1996 to 2005 period, although graduations of technologists (3.73 per cent) increased the most over this period.

Figure 1.1 Employment trends (averages per 2-year periods) for engineers and technologists and technicians, 1996-2005



	1996-1997	1998-1999	2000-2001	2002-2003	2004-2005
Engineers & technologists	17810	21589	25242	28606	27764
Technicians	25470	29020	32599	34417	45535

Source: Quantec 2007

1.3.2 Employment of engineering professionals across the public and private sectors of the economy

In order to understand the state of the engineering profession in South Africa, it is necessary to consider the sectors engineers engage in. In a broader sense engineers are at the core of two key areas of development enterprise in the country: building and maintaining infrastructure in the public sector; and contributing towards economic growth in the private sector. These are fundamentally different contexts in terms of the kind of engineering work undertaken and the conditions of employment.

In the public domain, engineers in the employ of the parastatals have always been involved in the provision of transport, communication and electrification. Those specifically in the civil engineering field are involved in general urban development and upgrading of infrastructure and are by and large employed by local or provincial government. In the private sector engineers are working in a wide range of commercial enterprises including small consulting firms, medium-sized businesses, and large multinational companies. There are also sizeable contingents of engineers who are not working in the traditional engineering sector. Many of these are active in the financial and general business sector as reported in Table 1.3.

Employment distribution across the different economic sectors of the economy

Table 1.3 shows that there was substantial ebb and flow in the availability of engineering employment in the various sectors in the economy between 1996 and 2005. The shifts in employment of engineering professionals in the sectors of the economy are noteworthy. The dramatic fluctuation within sectors is a good illustration of the intra-sectoral factors affecting employment. These factors usually relate to the following: the effects of the business cycle; the free enterprise nature of society – South Africa doesn't have a planned economy and engineering professionals deploy themselves in sectors due to various reasons; the type of employment arrangements that exist in the industry; and the nature of supply of the skills from the higher education sector (Interview 2006c; Steyn & Daniels 2003). Stakeholders in the engineering industry have specifically raised concerns about the employment arrangements made through labour brokers especially for technicians (Interview 2006b; Interview 2006a). The experience is that labour brokers are not committed to ensuring training and continuity of work for employees who are on their payrolls. In the 1990s when the economy was going through an operating and maintenance phase, large numbers of technicians were retrenched from state-owned enterprises such as Eskom. Labour brokers absorbed these employees, and the tendency is to place them on short contracts in different work environments across sectors (Interview 2007a).

Over the period 1996 to 2005 the majority of engineers and technologists worked in the manufacturing and financial and business services sectors. It makes sense for engineering professionals to work in manufacturing (24.99 per cent), but it is significant that on average, 25.17 per cent worked in finance. The significant number of engineers who are employed in the financial and business services sector is an indication of the proportion of consulting engineers working either for large financial and management consulting companies or in smaller independent engineering consulting operations. It is well known that management consultancies often recruit top engineering graduates. The South African Association of Consulting Engineers (SAACE) reports that, over the years, its membership has grown from 30 individual members in 1952 to 420 firms in 2002, which employ more than 12,500 people in total (SAACE 2006). The large number of engineers working in the financial and business services sector may not apply their technical skills, but they assist the industry with risk management through consulting agencies (Interview 2006d). This is a controversial issue that may contribute to the difficulties in dealing with the shortages in areas where their skills can be utilised more appropriately, such as in civil engineering, the local authorities and Eskom.

Construction is a labour-intensive industry that is very dependent on the domestic market and in which the public sector is dominant. On average per annum, only 9.02 per cent of engineering professionals were employed in the construction industry over the 1996 to 2005 period. Construction declined throughout the 1990s because of the government's policy of curtailing expenditure. In 2005, however, the construction industry grew at a growth rate of 4.8 per cent nationally. Table 1.3 reports an increase in employment from 2003 to the present.

The Accelerated and Shared Growth Initiative for South Africa (ASGISA), with a capital investment of R372 billion over the next five years (2006-2010) for infrastructure work, will surely stimulate and ensure growth of the construction sector. According to Sam Amod, 'The industry is faced with the prospects of a boom in infrastructure construction and industrial projects at a time when its skilled resources are reduced to critical levels and many of its civil engineering professionals are approaching retirement'.[11] Suitably skilled people will be needed

11 Civil engineering students in demand *Express* 31.03.2006

to drive the massive infrastructure programme under ASGISA, but current skills shortages in local government will impede the rollout of the programme.

A few initiatives are attempting to address this problem. ECSA and the civil engineering profession are assisting local governments by mobilising retired engineers to help the staff of local authorities prepare projects for implementation (Interview 2006c). The South African Institution for Civil Engineering (SAICE) and the Local Government SETA are involved in a programme that awards bursaries to technicians who work in local authorities (and there has been quite a substantive increase in the number of technicians over the 2002 to 2005 period, as shown in Figure 1.1). The South African Institution for Consulting Engineers has signed a Memorandum of Understanding with the Department of Provincial and Local Government to provide capacity in the hardest-hit local authorities (Interview 2006d). The strategy is to marry an engineering firm with a local authority in order to build technical and management capacity.

Table 1.3 Distribution of engineers, technologists and technicians by economic sector, 1996-2005

Engineers, technologists and technicians per economic sector	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	Total	Average working per year	% Average annual growth
Engineers & technologists	0	1013	1385	1615	3133	946	2282	2170	1910	210	14665	1466	-17.87*
Technicians	1852	1626	2327	1256	2271	2136	3053	1078	734	2300	18632	1863	2.44
Mining and quarrying: Total	1852	2639	3711	2871	5405	3082	5336	3248	2643	2510	33296	3330	3.43
Engineers & technologists	3841	3737	3410	5314	2832	11104	11906	5939	6586	5906	60575	6057	4.90
Technicians	4951	4204	4528	7454	6382	7694	13251	8071	8365	12360	77260	7726	10.70
Manufacturing: Total	8792	7941	7937	12769	9214	18798	25156	14010	14952	18266	137835	13784	8.46
Engineers & technologists	523	3245	3502	1359	843	2187	1632	1828	669	3473	19260	1926	23.41
Technicians	3720	2624	7109	312	1234	1056	2816	648	2433	2333	24284	2428	-5.05
Electricity, gas and water supply: Total	4243	5869	10611	1671	2077	3243	4448	2476	3101	5806	43545	4354	3.55
Engineers & technologists	5532	1216	5588	1471	2214	3181	1351	1751	1842	9013	33160	3316	5.57
Technicians	1327	1223	3231	890	3335	0	1510		4290	765	16572	1657	-5.93
Construction: Total	6859	2439	8819	2361	5549	3181	2862	1751	6132	9779	49732	4973	4.02
Engineers & technologists	760	362	0	1197	1100	2916	0	322	0	0	6657	666	0
Technicians	3663	1196	569	1523	2948	3218	4710	2105	1581	6155	27667	2767	5.94
Wholesale and retail trade: Total	4423	1558	569	2720	4048	6134	4710	2427	1581	6155	34325	3432	3.74
Engineers & technologists	1883	891	0	852	2992	0	3673	3944	2054	3113	19402	1940	5.75
Technicians	7105	3107	3111	6730	7506	6068	3467	5566	2561	6886	52107	5211	-0.35
Transport, storage and communication: Total	8988	3998	3111	7582	10498	6068	7139	9510	4615	9999	71509	7151	1.19
Engineers & technologists	2652	2522	9827	5877	9752	5271	11274	4173	5361	8485	65195	6519	13.79
Technicians	1528	3338	7951	5428	11208	6429	5941	11977	8699	11091	73590	7359	24.64
Finance: Total	4180	5860	17778	11305	20960	11700	17215	16150	14060	19576	138785	13878	18.71
Engineers & technologists	1065	1715	442	634	370	2302	1750	2101	3760	3144	17283	1728	12.78
Technicians	4856	3544	3383	2238	1907	782	1301	1541	1895	3717	25164	2516	-2.93
Community, social and personal services: Total	5921	5259	3825	2872	2277	3084	3051	3642	5655	6861	42447	4245	1.65

Notes: *1997-2005

(Source: Quantec 2007)

Public-Private distribution

A quarter (25.15 per cent) of engineers, technologists and technicians worked in the public sector in 2000 and mostly for state-owned enterprises (Table 1.4). This figure decreased to 24.46 per cent in 2005, as the private sector had more of a growth as the public sector over this period. The average annual growth rate for employment of engineering professionals in the public sector for the period 2000–2005 is 7.68 per cent, compared to 12.12 per cent in the private sector.

The increase in employment at provincial (23.32 per cent average annual growth) and local (10.30 per cent average annual growth) government levels is heartening, although 2000 to 2005 is a short period to measure average annual growth. The expansion of infrastructure spending by government over the next few years will lead to further demand for engineering professionals in the public sector but, with the current rate of reported skills shortages, it will not be easy to fill the vacancies. There are around 2 000 vacancies in municipalities in the country, according to Dawie Botha, executive director of the SA Institute of Civil Engineering.[12] It is recommended that they should be filled by teams, each consisting of a recently retired senior engineer and two or three younger graduates (Lawless 2005).

Growth in both categories (engineers/technologists and technicians) is most probably as a result of more technologists and technicians being supplied by tertiary intitutions, rather than engineers, as technologist graduations increased with an annual average of 3.73 per cent, technician graduations with 2.50 per cent and engineer graduations only with one per cent over the 1996 to 2005 period (Table 2.2 – graduations). Furthermore, over the past few years there has been a decline in the ECSA engineer registration and an increase in the technologist/technician registration.[13] Inexperienced technicians and at times non-technical staff are found running technical departments and project management units where there are no civil engineers - decisions are thus deferred, not made at all or made inappropriately (Lawless 2007). Delays in the supply chain management process occurred because procurement had become centralised rather than the duty of each department, according to engineers seconded to struggling municipalities.[14]

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12 Universities running empty *The Star* 9.08.2008

13 SAIMC professional development and training *SA Instrumentation and control* February 2005

14 Engineers warn of dire straits in local councils *Business Day* 2.03.2007

Table 1.4 Distribution of engineers, technologists and technicians by public and private sector, 2000 and 2005

Sector	2000			2005			% Average annual growth
	n	%		n	%		
All engineering professionals (engineers, technologists and technicians)							
Central government	2103	13.93		1329	6.08		-8.77
Provincial government	1107	7.34		3159	14.46		23.32
Local government	1240	8.22		2025	9.27		10.30
State-owned enterprises	10646	70.52		15338	70.19		7.58
Total public sector	15097	100	25.15	21851	100	24.46	7.68
***Private sector**	38088		63.45	67473		75.54	12.12
Unspecified	6840		11.40	0		0	
Total	60025		100	89324		100	8.27
Engineers & technologists							
Central government	2103	40.27		1082	10.02		-12.45
Provincial government	370	7.08		828	7.67		17.50
Local government	0	0		809	7.50		
State-owned enterprises	2750	52.65		8075	74.81		24.04
Total public sector	5222	100	23.51	10794	100	32.37	15.63
Private sector	13486		60.71	22552		67.63	10.83
Unspecified	3504		15.77	0		0	
Total	22212		100	33346		100	8.47
Technicians							
Central government	0	0		247	2.24		
Provincial government	738	7.47		2331	21.08		25.87
Local government	1240	12.56		1216	11.00		-0.40
State-owned enterprises	7896	79.97		7263	65.69		-1.66
Total public sector	9874	100	26.11	11057	100	19.75	2.29
***Private sector**	24603		65.06	44921		80.25	12.80
Unspecified	3336		8.82	0		0	
Total	37813		100	55978		100	8.16

Source: Quantec 2007
*Including private associations, private business, and self-employed
Note: Data for only 2000 and 2005 were compared, as data before 2000 was not available according to the above sector breakdown

1.3.3 Engineering professionals working as managers

In the South African context where there is a serious shortage of managers, as indicated by Professor Eon Smit, director of the University of Stellenbosch's Business School,[15] it is often found that engineering professionals become managers.[16] Following the initial training of engineering professional, opportunities for leadership positions usually arise very soon - in most contexts this would also involve either a continuation in the technical track or a move to a more managerial and business focused position (Case 2006). Engineers are more suited than others to adapt to the highly pressurised environment of banks' trading floors, according to Absa's Capital's head of trading[17] and industrial engineers are especially being snatched by the banking sector, as says Johan

15 A shortage of managers *Mail & Guardian* 15.04.2008

16 The ten best-paid jobs in South Africa *Citizen* 28.11.2006

17 Absa Capital puts spanner in engineer booster plan *Business Report* 10.07.2008

Pienaar, registrations manager at ECSA.[4] Historically, B.Sc. (Eng.) graduate engineers have tended to move more easily into management level positions than other engineering professionals have (Case 2006). It is crucially important to note however that the management functions that an engineering professional performs are strongly rooted in the technical exposure that they have received in the earlier years of their training (Case 2006). Three decades ago project management was seen mainly as a sphere of engineering and construction, says Terry Deacon, an experienced engineering professionals.[18]

The levels of leadership that an engineer would be able to perform would tend to change over the course of a career (Case 2006). A good example is Danai Magugumela, first black women CEO at BKS Consulting Engineers, who started off as a civil engineer with the Texas Department of Transportation, joined a consulting firm in Cape Town, yet another consulting engineering group, then moved to the public sector for four years as project manager at the Municipal Infrastructure Investment Unit and then moved on to the entrepreneurial environment.[19] Engineers with approximately 10 years experience would likely be supervising specific technical work (Eddie Durant, Grinaker-LTA managing director, 2007)[20] while many of those with more experience would be at the helm of large corporate or public sector enterprises (Case 2006). The CEO of the Coega IDZ, Pepi Silinga, is an example of a leader with an engineering qualification, a MBA and development programme experience who has successfully promoted co-operation between provincial and national government levels, and parastatal enterprises by ensuring delivery to communities.[21] According to Table 1.4, on average, a third of those with a professional engineering qualification worked as managers during the period 1997-2005. The number of engineer working as managers almost doubled over the period 1997 to 2005.

Only around half of those that were trained to be engineers, end up doing engineering work, while the other half work in other industries, according to Mr. Alec Erwin, minister of State Enterprises.[22] Engineers are poached by other industries because of their analytical skills, according to Johan Pienaar, registrations manager at ECSA.[4] This ‘internal poaching’ of engineers contributes to a shortage in experienced engineers (David Carte, reporter, 2006).[16] The engineering profession has been neglected for years with regards to remuneration[16] and lack of public sector investment (Dave Marrs, editor, 2007).[10] but fortunately is making a comeback currently with more infrastructure spending.[16] However, executive level remuneration are still more attractive than wages of technical workers, according to Sandra Burmeister, CEO of Landelahni

18 Keeping things on track *Mail & Guardian* 1-7.08.2008

19 Engineeringt Transformation; ‘Retain talent irrespective of race or gender’ *Engineering News* 23-29.06.2006

20 Skills shortage is genuine threat to growth, say bosses *Business Repo*rt 24.05.2007

21 The captain of Coega’s ship *Enterprise* 30.11.2005

22 Regstel-aksie is dood, sê Erwin *Beeld* 12.07.2007

Business Leaders[7] and Dirk Hermann, Solidarity general secretary.[23] Furthermore, appointment policies, especially at local government level, will have to change if more technical skills need to be attracted, according to Webster Ndodana, owner of a consulting engineering firm – technical staff are currently appointed at lower levels than previously and this creates the image that there is no career paths for those with technical skills in this sector.[24] Young engineers are frustrated by the lack of on-the-job training and lack of opportunities to learn from others with more experience.[19] Career paths for engineers and continuing professional development need to be addressed in a bid to keep technical skills where it is most needed (African Academy, 2007).[25]

Underutilisation of engineers could also contribute to frustration in a technical environment – engineering graduates were for example being deployed to building sites, because construction companies could not find enough artisans, said Carl Grim, CEO of Aveng.[26] According to Sigi Proebstl, chief executive at Siemens South Afrtica, the market requires one engineer for every four technicians and every 16 artisans,[27] while currently the ratio stands at one engineer for every 1.38 technician (Table 1.2) and two artisans.

A combination of factors thus contributes to engineering professionals leaving the technical environment. The adaptability of engineering skills in many environments, insufficient incentives, appointment policies, lack of opportunities to get the required experience, lack of continuing professional development, insufficient career paths, underutilisation of engineers (because of too few technicians and artisans available) in some environments, and under qualified engineering staff in other environments such as at local government level because off a shortage in engineers, all contribute to migration of technical skills to more lucrative environments. Workplace culture, growth opportunities, flexible employment practices, valuing diversity, reward systems, employment equity, and broad based black economic empowerment are some means to address shortcomings in the working environment of technical staff, according to Professor Frank Horwitz, director of the UCT Graduate School of Business.[28]

Managers with 'engineering related' qualifications include fields of study such as engineering, manufacturing and technology and not only pure engineering, as managers in the OHS and LFS datasets cannot be identified according to pure fields of study. Managers with 'engineering related' qualifications, which are not included among engineering professionals (those with pure engineering degrees and national diplomas in Table 1.1. and Table 1.2) make up just over a quarter (27.44 per cent) of those (engineers, technologists, technicians and engineering managers) working in the engineering environment (Table 1.5).

23 Better pay, incentives may save SA from skills shortage *Business Day* 6.07.2007

24 'Gebruik die kundige ingenieurs' *Rappor*t 22.01.2006

25 Addressing skills shortage in engineering field *Star* 23.05.2007

26 Aveng hurt by skills lack *Business Day* 12.01.2007

27 Setas receive funds to address SA's skills crisis *Sowetan* 17.05.2007

28 Need for skills shortage solution *The Herald (EP Herald)* 30.11.2006

Table 1.5 Percentage of people with 'engineering related' qualifications working as managers, 1997-2005

	1997	1998	1999	2000	2001	2002	2003	2004	2005	Total	%
Engineers & Technologists (with degrees)	15729	24153	19024	22212	28272	33868	23343	22181	33346	222128	30.56
Technicians (with national diplomas)	22110	32208	25831	37813	27384	36049	32784	35091	55978	305250	42.00
Managers*	15247	12163	12506	24292	24309	30165	23829	28449	28449	199410	27.44
Total employment	53086	68524	57362	84317	79965	100082	79956	85721	117773	726788	100

Source: Quantec 2007

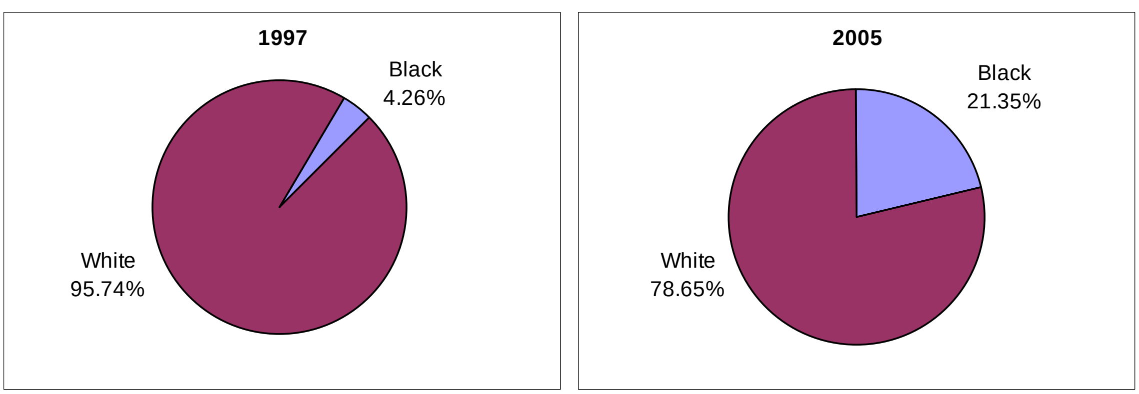
*People working as managers with a qualification in an 'engineering related' field and not counted with engineering professionals in Table 1.1 and Table 1.2

Note: Numbers differ from Table 1.1 and Table 1.2 as this table excludes 1996

Figure 1.2 reports the distribution of managers according to race and Figure 1.3 according to gender. In 1997 less than five per cent of people who had a qualification in an engineering field and who held a managerial position were black – the category 'black' comprises Africans, coloureds and Indians. (See preface for an explanation of the racial analyses in this report.) This figure increased to just over a fifth (21.35 per cent) in 2005.

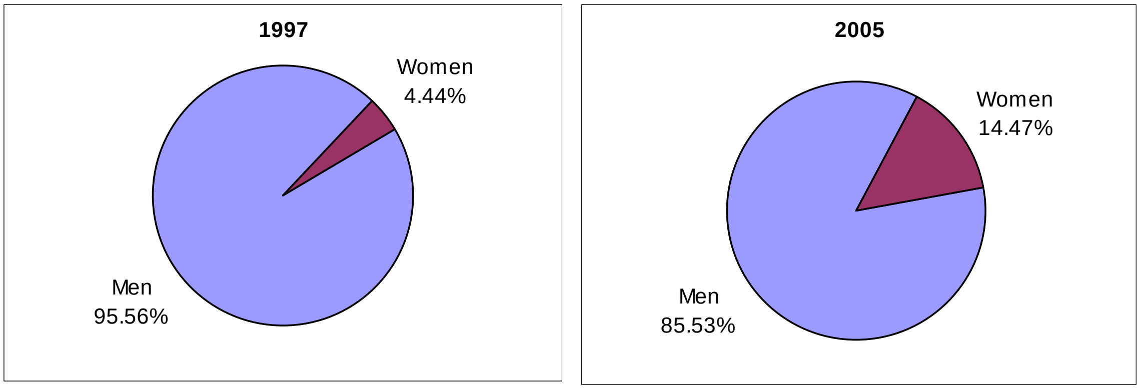
The trend was less favourable for women than for blacks. In 1997 only 4.44 per cent of managers were women and this figure only increased to 14.47 per cent in 2005.

Figure 1.2 Distribution of managers with engineering related qualifications according to race, 1997 and 2005



Source: Quantec 2007

Figure 1.3 Distribution of managers with engineering related qualifications according to gender, 1997 and 2005



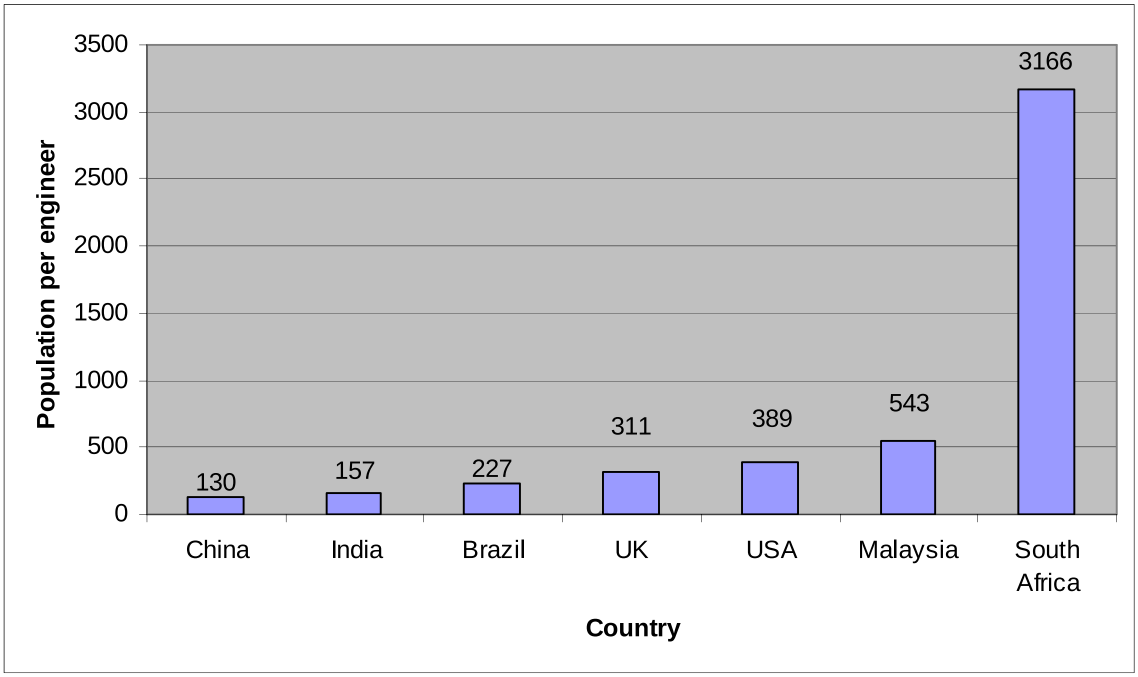
Source: Quantec 2007

1.3.4 Employment ratios of engineering professionals

One measure of economic prosperity in a country is the number of engineers supplied per million citizens per annum. When international benchmarks such as the ratios of engineers to population are cited, it is usually grounded on figures from the professional registering bodies of each country. Most of the registering bodies comparable to ECSA merely quote the number of professional engineers registered at a specific point in time.

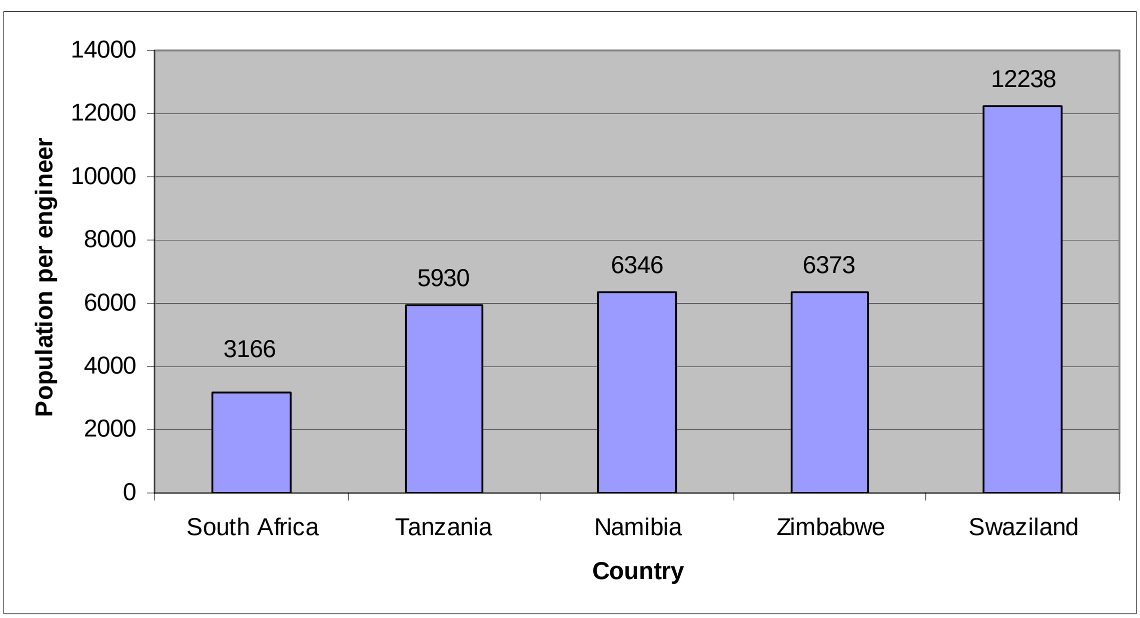
Figure 1.4 provides the ratio of registered engineer to population in South Africa compared to the ratio of registered engineer to population in a few developed and developing countries (outside Africa) based on the ECSA number of 14 806 professional engineers registered at that time. Figure 1.5 shows the ratio of registered engineer to population in South Africa in comparison to the ratio of registered engineer to population in some African countries. Currently there is about one registered engineer for every 3 166 citizens in South Africa – South Africa is becoming more backward in this regard, as in 1972 there were 2 000 people per engineer (Interview 2006f). It is generally known that South Africa is technologically stronger than other African countries and it is thus not surprising that the ratio of registered engineer to population is more favourable in South Africa than in other African countries. It is, however, disquieting that the ratio of population to engineer in South Africa is not significantly better than Zimbabwe, Namibia and Tanzania and other less developed countries, given that South Africa needs to develop and strengthen its infrastructure (Lawless 2005). It must, however, be kept in mind that the definition of engineer varies from one country to another and this makes it difficult to compare countries with regard to the number of engineers. The engineer to population figure would look better if real employment figures or counts of engineering professionals are used. If the number of employed engineers in South Africa in 2004 (22 182) according to the LFS (2004) is used, it translates to one engineer for every 2 113 people, which is a more favourable ratio than one engineer for every 3 166 people, although still not much better than that of other African countries. Only half of the engineers that are trained end up in the engineering environment in South Africa, said Mr Alec Erwin, minister of Public Enterprises,[22] and this needs to be addressed through various incentives as mentioned in paragraph 1.3.3.

Figure 1.4 Registered engineer to population ratios in developed and non-African developing countries, 2004



Source: Lawless, 2005

Figure 1.5 Registered engineer to population ratios in some African countries, 2004



Source: Lawless, 2005

The ideal ratio for engineers, technologists, technicians and artisans has been debated for decades. The ideal ratio between the four categories for most developed countries is one engineer for two technologists, four technicians and 16 artisans, according to the general secretary at the South African Institute of Measurement and Control (SAIMC).[13] ECSA and the Engineering Association of South Africa (EASA) proposed a ratio of one engineer to one technologist to 4 four technicians to 16 artisans for the South African context (ECSA & EASA 1995). According to Quantec employment data (1996-2005), the ratio of engineers and technologists to technicians is about 1 : 1.4 (OHS and LFS do not differentiate between engineers and technologists).

Supply data, however, does differentiate between engineer graduations and technologist graduations. If the supply (output) ratio of graduate engineers to graduate technologists at tertiary institutions is applied to the Quantec data over the 1996-2005 period, the ratio of engineer to technologist to technician is approximately 1 : 0.4 : 1. This means that for every technologist there are just more than 2 engineers. Such a ratio implies that engineers are underutilised, doing the work of technologists or even technicians in some instances, a fact that was confirmed by several stakeholders in the engineering industry. The CEO of Aveng, Africa's biggest builder, mentioned that engineering graduates were being deployed to building sites because construction companies could not find enough welders and other workers.[26]

Indications are that technologists with BTech degrees are also frequently being underutilised, at least in the private sector, and are used in very similar positions to technicians. In the public sector there does seem to be some evidence that technologists are being fast-tracked to take up positions historically filled by graduate engineers and according to Table 1.1 there seem to be quite a number of national diploma graduates that are also employed to do work where engineers are absent. Concerns have been raised about the suitability of this (Lawless 2005).

1.3.5 Demographic profile of engineering professionals in terms of race, gender and age

In order to smooth effects of fluctuations in data an average was created for the period covered by each survey. Thus, for the OHS which ran for a period of four years from 1996 to 1999, an annual average employment number was generated. Similarly, for the six year period from 2000 to 2005, an average employment number was created.

Race and gender

The race profiles of employed engineers and technologists are presented in Figure 1.6 and for technicians in Figure 1.7 and the gender profiles in Figure 1.8 and 1.9. The averages for 1996-1999 (OHS) and 2000-2005 (LFS) data were used to get an indication of the transformation trends (Quantec 2007).

Blacks represented 15.47 per cent of all engineers and technologists over the 1996-1999 period. This percentage almost doubled to just under a third (30.47 per cent) over the 2000-2005 period. Black technicians constituted over a quarter (28.57 per cent) over the period 1996-1999 and increased with slightly fewer percentage points (12.81 per cent) than black engineers and technologists to 37.51 per cent over the 2000-2005 period.

The average number of Indian engineers and technologists increased with 1 625 (proportionally from 7.91 to 22.72 per cent), coloured engineers and technologists with 797 (proportionally from 11.02 to 13.75 per cent) and African engineers and technologists with 2 779, although proportionally less than coloureds and Indians over the 1996-1999 to 2000-2005 period.

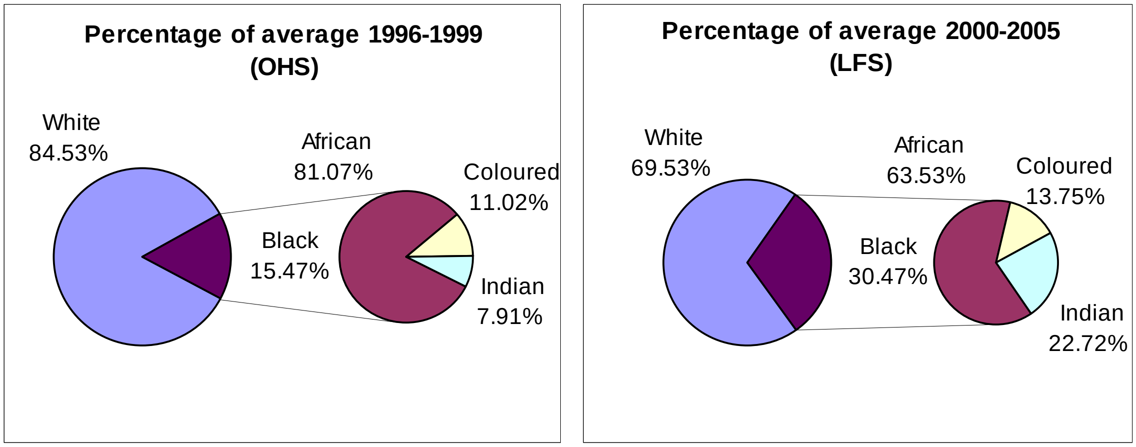
The average number of African technicians increased with as much 6 614 (proportionally from 59.98 to 72.60 per cent), coloured technicians with 1 198 (although they decreased proportionally to African technicians) and the average number of Indian technicians decreased with 45 over the 1996-1999 to 2000-2005 period.

Conversely, the employment of women engineers, technologists and technicians decreased over the whole 1996 to 2005 period. On average 11.36 per cent women were employed as engineers and technologists over the 1996-1999 period, but this figure dropped to under 10 per cent (8.48 per cent) over the 2000-2005 period, despite the fact that the supply of women graduates at tertiary institutions increased at an annual average rate of 15.37 per cent over the 1996 and 2005 period (DoE 1996-2005). It is noteworthy to mention that the decrease in the employment of white women engineers and technologists over this period is primarily responsible for this negative trend. More of a downward trend is noticed for women engineering technicians (see Figure 1.9). Reasons for the decrease in the employment of women in the engineering industry are discussed in chapter 3.

Although the average number of white, male engineers and technologists increased with as much as 3 041, in proportion to other population groups they decreased from 84.45 per cent to 71.20 per cent over the 1996/1999 to 2000/2005 period. The average number of African, male engineers and technologists increased with 2 000 (proportionally from 12.25 to 16.66 per cent), Indian, male engineers and technologists increased with 1 625 (proportionally from 1.38 to 7.57 per cent), and coloured, male engineers and technologists increased with 797 (proportionally from 1.92 to 4.58 per cent) over this period.

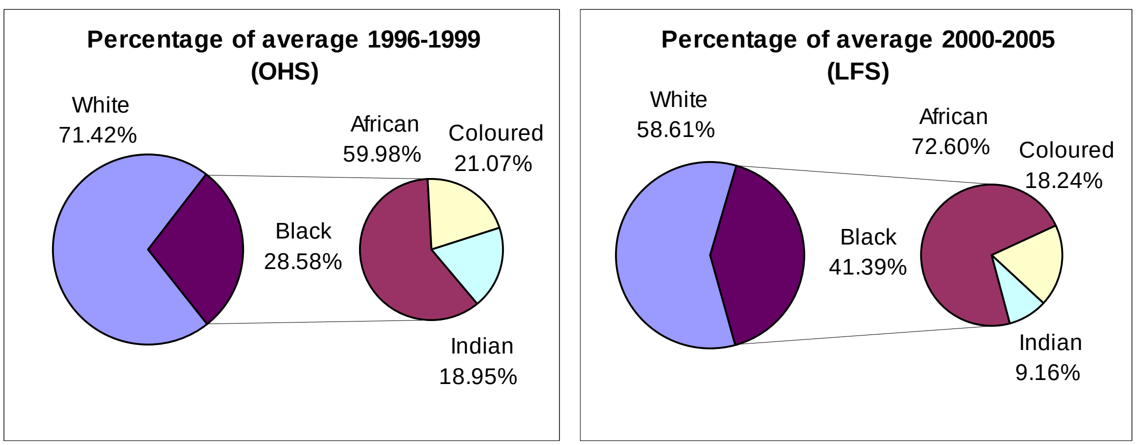
The average number of African, male technicians increased with as much a 6 679 (proportionally from 15.89 to 30.54 per cent), coloured, male technicians with 889 (proportionally from 6.31 to 6.96 per cent), Indian, male technicians increased with 145 (although proportionally from 4.51 to only 3.54 per cent), while white, male technicians increased with 2 832 (but proportionally from 73.30 to only 58.96 per cent) over the same period.

Figure 1.6 Race profiles of engineers and technologists, average for 1996-1999 (OHS) and average for 2000-2005 (LFS)



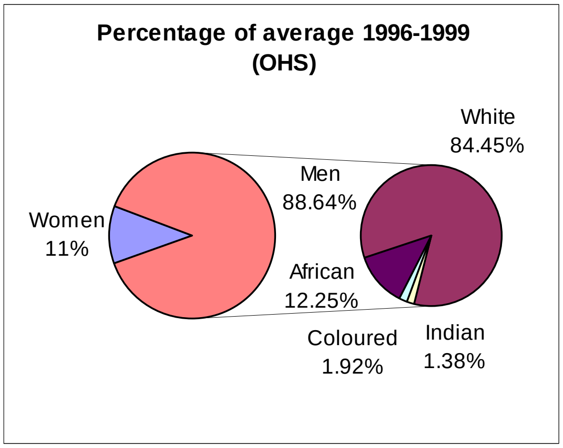
Source: Quantec 2007

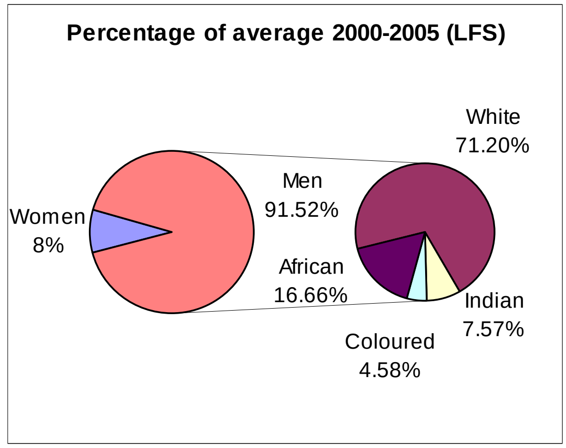
Figure 1.7 Race profiles of technicians, average for 1996-1999 (OHS) and average for 2000-2005 (LFS)



Source: Quantec 2007

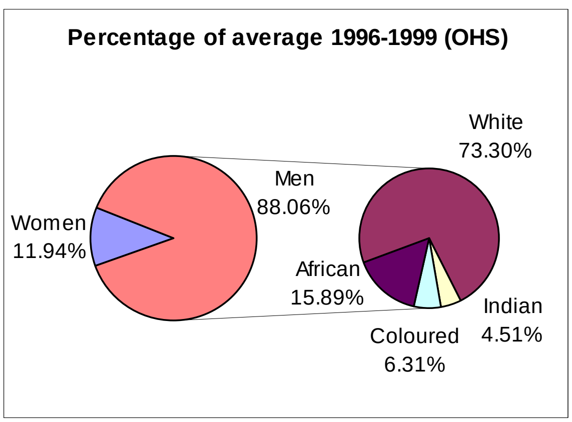
Figure 1.8 Gender profiles of engineers and technologists, average for 1996-1999 (OHS) and average for 2000-2005 (LFS)

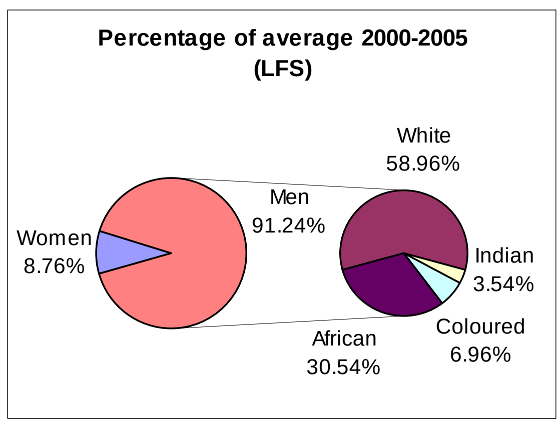




Source: Quantec 2007

Figure 1.9 Gender profiles of technicians, average for 1996-1999 (OHS) and average for 2000-2005 (LFS)





Source: Quantec 2007

Age

Figure 1.10 shows the age profile of engineers and technologist and technicians in the labour market in 2005. The greatest population density of engineers and technologists occurs between the age 35 and 39 – more than half (55.70 per cent). These engineers and technologists (age 35 to 39) in 2005 were students around 20 years ago (during the 1980s). Construction peaked in the 1970s and 1980s, according to Peter Squires, director at VKE[29] and attracted engineering

29 With bridge-building prospects improving, SA mulls skills-dearth challenge *Engineering News* 7.07.2006

students at that time. From 1986 to 2003 civil engineering first-degree graduations declined (Lawless 2005), as construction slowed in the 1990s.[29] This may explain the concentration of engineers in the 35 to 39 age category.

A major shortage of older and experienced professionals is noticed - only 13.01 per cent of engineers and technologists are in the age category 50 to 60^{+}. This has a major impact on the transfer of skills to the younger generation of engineering professionals, according to Vanesh Maharaj, a partner with Development Engineering and Consultants (DEC).[30]

The profile also indicates a shortage of mid-career professionals between the age 40 and 49. According to Lawless (2005) this low figure further shows that this middle group, having gained experience, are the ones sought after globally. Althea Povey, a former president of SAACE, explains that it may be that industry does need more engineers but cannot afford to take on young graduates, who require time and money to train, and so the hunt is always for the older experienced engineers who are scarce.[31] One of the key issues in the engineering industry at the moment is the lack of mentors, as indicated by Sean Flanagan, executive director of Murray and Roberts.[30]

All engineering professionals start out in training positions that are largely technical based. Initially workplace training would usually fulfill the requirement for professional registration, should it be sought (Hanrahan 2000). Lawless (2005) has found that in a substantial proportion of civil engineering contexts, engineering professionals in this training stage, especially graduates, are not getting basic supervision and assistance from older professionals. There are too few of the latter, and they have too much work to be able to pay attention to the transfer of skills. Anecdotal evidence suggests that this situation also pertains across other engineering disciplinary contexts. Most of the large corporate companies used to operate substantial graduate training programmes for in-depth training, many of which now only exist in a very pared-down format. Graduates are now expected to 'add value' as soon as possible after their entry to the workplace (Adams 2006). Elsewhere in the world, the retirement ages are being raised to retain expertise in order to mentor younger engineers. This might be an option for South Africa as well.

The very low number of engineers and technologists younger than 35 is noteworthy. Supply data from DoE indicate that on average about 2 700 graduates (engineers plus technologists) per annum were delivered for the period 1996 to 2004 – that equals just over 25 000 over the nine-year period. This means that about 25 000 graduates should have entered the labour market since 1996. But where are they? One explanation could be low registration, because some could still be candidate engineers or technologists. LFS data for 2005 show for instance that about 8 000 people with engineering degrees worked as technicians – this is an example of underutilisation. Another reason is that young graduates leave South Africa to gain experience abroad (Interview

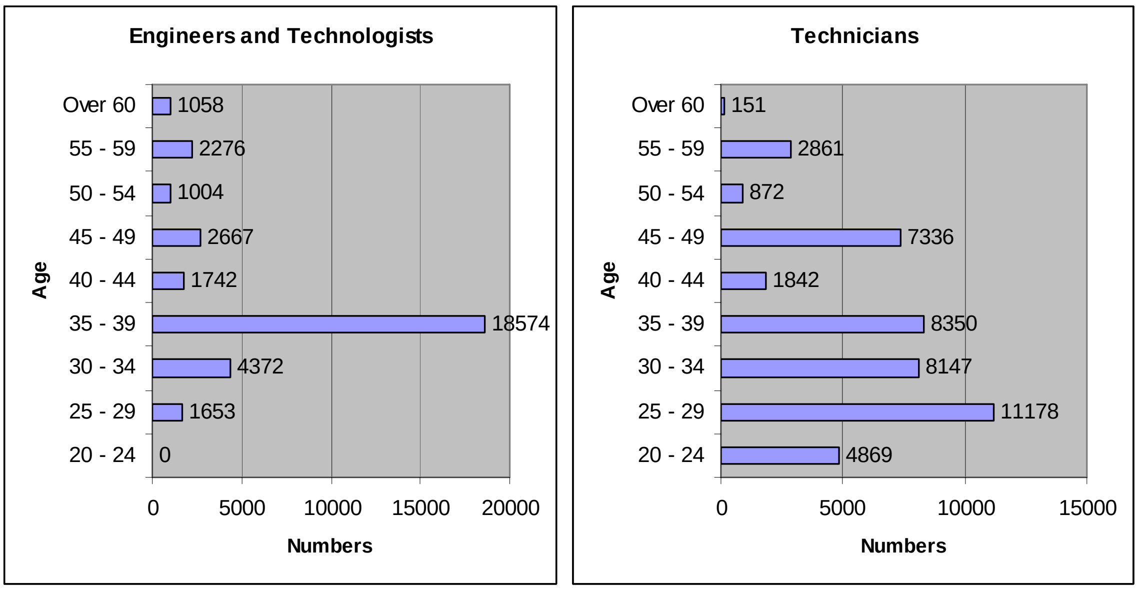
30 Hunt turns offshore for senior-professionals to fill SA's skills gap *Sunday Independent* 01.07.2007

31 SAACE president questions assertions on the shortage of engineers *Inside Track* 3.03.2005

2006f). The international agreements such as the Washington Accord for engineers (Jones 2006) and the Dublin Accord for technologists augment this possibility (Interview 2006h).

In terms of the age profile for technicians it shows that three quarters (75.40 per cent) of the technician workforce is under the age of 45, which makes the task of the very few older technicians to transfer the necessary skills in the workplace virtually impossible. The picture reflects the earlier starting age of technicians with a career – a technician graduates after a three-year National Diploma.

Figure 1.10 Age profile of engineers and technologists and technicians, 2005



Source: Quantec 2007

1.3.6 Remuneration trends for engineering professionals

Compared to other professions such as medicine and chartered accountancy, it is well known that engineers traditionally earn less. Lower remuneration as well as an apparent lack of glamour associated with engineering is thus some of the major factors influencing potential students when making career decisions.

Lawless (2005) reports that low salaries were seen as a key frustration, especially for engineers aged 35 to 55 years in the civil engineering sector. Her findings further show that salary disparities between civil engineers and other professionals appeared to be most notable in younger groups, which contributes to the movement of young professionals to other industries. This trend is not unique to South Africa. Lawless refers to a recent study by the Higher Education Statistics Agency in the UK that found that more than half of engineering graduates defect to other careers, citing money, status and image as the main reasons. According to Lawless, graduates in the UK could command double the starting salary offered to them in engineering by joining the finance and business sectors. In South Africa this is also a worrying trend in terms of engineering professionals as an already-alarming skills shortage is being exacerbated because local professionals are drawn to other markets and industries because of higher salaries.

However, remuneration trends can be an indicator of the demand for certain skills and parity in terms of demographics i.e. race and gender. Industry stakeholders are generally reluctant to provide salary data, and quantitative surveys on the matter are, as a rule, confidential and only available to participants. LFS data for the period 1997-2005 was therefore used to get an estimate of remuneration trends for engineering professionals. The data show an average annual increase in engineering technicians' salaries of 8.89 per cent and for engineers and technologists 12.88 per cent over the period. The average annual growth of the salaries of women technicians over the same period was 17.23 per cent compared to 7.41 per cent for men, and 19.19 percent for women engineers and technologists compared to 11.73 for men. The average annual growth of the salaries of black technicians compared to white technicians was the same – about 8 per cent – but better for black engineers and technologists compared to whites – 16.21 per cent for blacks and 11.25 per cent for whites.

The managing director of Engineering Work Solutions – a recruitment and placement agency for engineering professionals in the construction industry – indicated that salaries have increased by 25 per cent and more the past year (Interview 2007a). Graham Pirie, CEO of the South African Association of Consulting Engineers confirms this by referring to the noticeable effect on profitability in the industry, caused by an increase in salaries because of the apparent scarcity of skills in some areas.[32] P-E Corporate Services reported that the shortage of technical, engineering and manufacturing staff increased the salaries for this group compared to other employees.[33] Attraction and retention of scarce and critical skills is still the single biggest driver of remuneration policy in private, public and state owned enterprises and the shortage of engineering professionals is impelling organisations to consider higher salaries which resulted in salaries increasing four or five times in the past three years, according to Vanesh Maharaj, partner with Development Engineering and Consultants (DEC).[30] Lawless (2005) emphasizes that it is necessary to dramatically increase salaries in order to address the skills shortages specifically for civil engineering professionals.

Within civil engineering, apart from the self-employed, civil professionals in JSE-listed companies are the highest earners, followed by contractors, with local government employees receiving the lowest average salaries. Local government and provincial remuneration levels have been identified as an area needing urgent attention, and there are large numbers of vacancies within provincial structures (Lawless 2005). Lawless suggests that engineering and other built-environment professions receive the same treatment as other comparable government employees - such as medical professionals - and be offered 'scarce-skills' and 'rural' allowances, to make public-sector employment more attractive.

32 *Mining weekly* 22.07.2007

33 Skills shortage 'drives up salaries' *Business Day* 1.06.2007

In the mining sector big contractors recently offered a sign-up bonus of R20 000 in an attempt to recruit skilled workers (Dirk Hermann, Solidariteit's general secretary, 2007.[23]

1.4 THE PROFESSIONAL MILIEU FOR ENGINEERING PROFESSIONALS

The Engineering Council of South Africa (ECSA) is a statutory body established in terms of the Engineering Profession Act, 2000 (Act No. 46 of 2000) and is the entity that registers engineering professionals in South Africa. ECSA is authorized by the relevant legislation to mainly carry out functions in terms of the education and training and registration of engineering professionals, the protection of the public interest with regard to engineering activities, and the recognition of professional associations, such as engineering associations, institutes, institutions and societies.

Because of the important role of the formal qualification for professional registration, ECSA operates a system of accreditation of the various engineering qualifications offered by tertiary institutions. The Council is responsible for setting and auditing of academic standards for purposes of registration through a process of accreditation of engineering programmes at universities and technikons, and setting and auditing of professional development standards through the provision of guidelines which set out the post-qualification requirements for registration. ECSA further prescribes the requirements for Continuing Professional Development (CPD) and determines the period within which registered persons must apply for renewal of their registrations.

ECSA is currently also engaged in the project 'Identification of Work". The main purpose of this project is to identify work in South Africa to ensure that work peculiar to the built environment is performed only by competent persons who are registered with a statutory council and who are accountable for their actions. This requires ECSA to consult with recognised voluntary associations, persons, bodies and industries that may be affected by any laws regulating the built environment professions regarding the identification of the type of engineering work which may be performed by persons registered in any categories provided for in Section 26(1) of the Engineering Profession Act,2000 (Act 46 of 2000).

A further responsibility of ECSA is to ensure that the interests of the profession are promoted. This occurs through the Council's recognition of voluntary societies which are active in engineering. The various engineering institutions are principally the South African Institution of Civil Engineering (SAICE), the South African Institute for Mechanical Engineering (SAIMechE), the South African Institute for Electrical Engineers (SAIEE), the South African Institute of Chemical Engineers (SAIChE), and The South African Association for Consulting Engineers (SAACE).

Registration with ECSA is still voluntary. Engineering professionals may register at ECSA after completion of their three year experiential training for engineers and technologist, and the one year for technicians. The difference between the engineers and technicians is that engineers graduates with a degree from a university and then work for a period of three years before they may register as a professional engineer at ECSA. The technicians complete two-years of theoretical training at a university of technology and still need to do one-year experiential training before they can obtain their national diplomas and register at the Council as a professional technician. However, registration with the Council is not compulsory as is the case with other professions such as medical doctors or psychologists. This means that the number of engineering professionals registered at ECSA does not compare to the number employed according to official labour market statistics.

ECSA recently announced an upsurge in registration due to awareness of the benefits of registration; eminent promulgation of the identification of Engineering Work regulations; possibility of compulsory registration; compulsory registration of Lifting Machinery Inspectors (as required by the Department of Labour); and an increase in the number of SADC and overseas engineering practitioners seeking registration and employment in South Africa.[34]

In terms of encouraging the transformation process the National Society for Black Engineers (NSBE) in South Africa is a good example of a forum with this objective in mind. It was established in 1995 and its initial aim was to focus on the academic progress of black engineering students at universities. The Society became a fully fledged professional body, legally registered as a non-profit, non-governmental organization in 1998. Since then a series of developmental programs for black engineers and student were undertaken. Monthly network sessions were held, usually within premises of companies employing black engineers. This would give black engineers an opportunity to share ideas, and the hosting companies an opportunity to inform potential employees about the activities of the firm.

Unfortunately the Society lost its impetus around 2002 - mainly because of lack of administrative resources and also because most of the office bearers had since assumed major responsibilities in their organizations. However, the declining number of technical skills in South Africa and the insufficient growth in the number of black engineering graduates brought about the revival of the organization. The NSBE held its first national conference in Durban in September 2007. The conference was about the NSBE's response to a call for more black participation and leadership in the technical fields that contribute to the economy of South Africa.

34 Engineering Council of South Africa reaches registration milestones *Engineering News Daily News* 3.07.2008

1.5 THE DEMAND FOR ENGINEERING PROFESSIONALS IN THE WORKFORCE

1.5.1 Guesstimated demand?

It is exceptionally difficult to come up with authoritative numbers or even estimates for skills shortages or demand for engineering professionals. The reasons are manifold: the quality of official statistics; double counting of especially engineering professionals in the Sector Skills Plans of Sector Education and Training Authorities in the face of infrastructure investment; absence of a comprehensive national register of qualified engineering professionals – it is not compulsory for engineering professionals to register with ECSA; the nature of the world-of-work for engineering professionals – they are easily absorbed in non-related industries; and unreliable emigration figures – engineering professionals maintain their registration status if registered, regardless of where they are working or what type of work they are doing and do not always indicate emigration because they leave the country to go an work on projects for only a duration of time. However, the following can be interpreted as signals of demand:

Growth in employment

Employment is usually used as an indicator of the demand for an occupation or skills. In the absence of regular and consistent survey data based on the needs of companies that use engineering skills, Labour Force Survey (LFS) statistics are used for the purpose of analysis of demand for employment. However, it is important to note that these data can only be used as a proxy for demand.

Table 1.2 reports an absolute employment gain of 40 605 in qualified engineering professionals (engineers, technologists and technicians) for the period 1996 to 2005, or an average annual growth of 6.97 per cent. This is more than double the average employment growth of 2.7 per cent for the total economy over the past five years. However, employment for engineering occupations is expected to increase even more in line with the massive infrastructure investment by government.

Vacancies

Skills shortages or the scarcity of specific skills are usually noticed in vacancies or positions for which employers cannot find suitable candidates. Table 1.6 shows vacancy data that were captured by the Department of Labour for the period April 2004 to March 2007. These data were obtained from all South African vacancies published weekly in the Business Times Careers section of the Sunday Times over that period. Although the vacancy rates cited below are only based on the Sunday Times data, it does signal that there is a demand for the skills of engineers and technologists in the South African labour market. Open any job section in any newspaper in the country and apart form domestic job advertisements; you'll see jobs offered to project managers and engineers in Australia, Singapore and New Zealand.

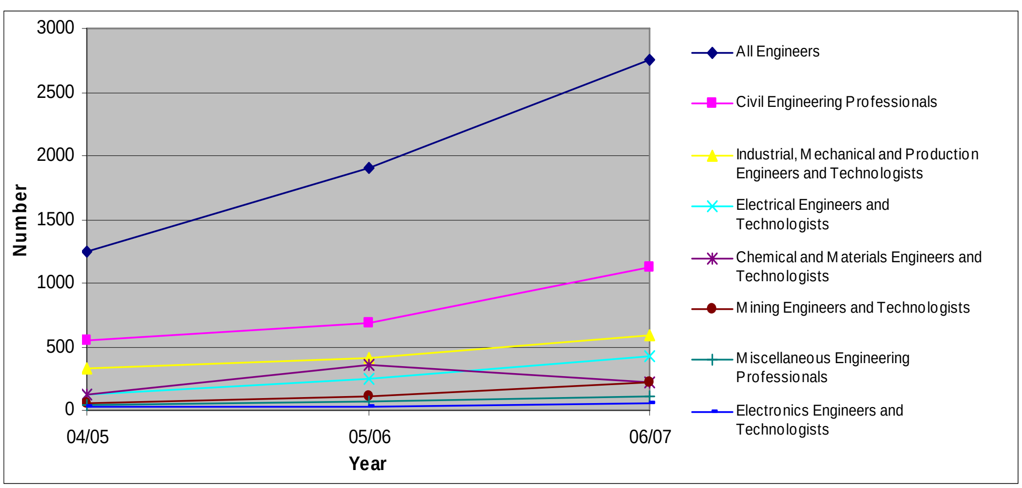
Table 1.6 Long-term vacancies reported in the Sunday Times, April 2004 – March 2007

	2004/2005		2005/2006		2006/2007	
	Vacancies	Vacancies as % of total employment	Vacancies	Vacancies as % of total employment	Vacancies	Vacancies as % of total employment
Engineers and technologists	1248	5.63	1904	5.71	2757	7.81

Source: DoL Vacancy data 2004-2007

Figure 1.11 and Table 1.7 shows that the number of vacancies increased significantly for all the engineering fields between 04/05 and 06/07, but the greatest percentage (387.72 per cent) was for mining and electrical engineers and technologists (Table 1.7).

Figure 1.11 Vacancies for engineers and technologists, April 2004-March 2007



Source: DoL Vacancy data 2004-2007

Table 1.7 Number of vacancies, April 2004-March 2007

	04/05	05/06	06/07	% increase
All Engineers	1248	1904	2757	220.91
Civil Engineering Professionals	546	688	1126	206.23
Industrial, Mechanical and Production Engineers and Technologists	326	409	594	182.21
Electrical Engineers and Technologists	121	243	430	355.37
Chemical and Materials Engineers and Technologists	123	355	221	179.67
Mining Engineers and Technologists	57	113	221	387.72
Miscellaneous Engineering Professionals	42	63	112	266.67
Electronics Engineers and Technologists	33	33	53	160.61

Source: DoL Vacancy data 2004-2007

Poaching of engineering professionals

According to engineering recruitment and placement agencies, there is extensive poaching of engineering professionals by overseas companies. "Highly skilled South Africans are being lured abroad by attractive pay cheques…" (Simpiwe Piliso, reporter, 2007).[35] The agencies indicate that if engineers go abroad, they don't come back. Like all professionals that are highly in demand, South African engineers are offered lucrative packages overseas and once they have experienced these conditions they do not want to give them up. According to Johan Pienaar, ECSA's registration manager, ECSA had 1 200 registered engineering professionals with overseas addresses on its database in 2007 - proper remuneration is required to encourage engineers to stay.[4] There is an aggressive head-hunt for engineers (Interview 2007a) and recruitment agencies from abroad are opening offices in the country.[36]

Ratios according to international benchmarks

As stated in section 1.3.4 there is about one engineer for every 3166 population in South Africa according to the conventional method of calculating this figure - quoting the number of professional engineers registered at a specific point in time. But in South Africa we know that very few qualified engineers register at ECSA because it is not compulsory. This means that the engineer to population figure would look better if real employment figures or counts of engineering professionals are used. If the number of employed engineers in 2004 (22 182) according to the LFS (2004) is used it translates to one engineer for every 2 113 people, which is a more favourable ratio than one engineer for every 3166 people.

Lawless (2005) emphasizes the fact that South Africa needs to develop and strengthen its infrastructure and that it is disquieting that the ratio of population to

35 Exodus – movement of the people *Sunday Times* 25.02.2007

36 Wêreld ontgin SA kundigheid *Finweek (Fin & Tegniek)* 16.11.2005

engineer in South Africa is not significantly better than Zimbabwe, Namibia and Tanzania and other less developed countries, as indicated in Figure 1.5.

1.5.2 New and replacement demand

The quality of current data on demand is not good enough in order to make forecasts with regards to new and replacement demand, because data fluctuates from one year to the next.

However, the domestic supply of young engineers and technologist is not visible in the local labour market, as there are very low employment figures for age category 25 to 34 (Figure 1.10). This issue has already been addressed in section 1.3.6 under the age profile of engineering professionals. If it is correct that many of the graduates leave the country to seek opportunities elsewhere in order to gain experience as Althea Povey, a former president of SAACE, stated an urgent strategy should be to assist young graduates to enter the South African labour market and incentive schemes should be put in place to retain them.

1.5.3 Reasons for shortages

An array of reasons can be put forward to try and explain the shortages of engineering skills. These may range from socio-economic factors such as economic growth and emigration; educational factors such as poor mathematics education at school, low throughput of engineering students at higher educational institutions to labour market intervention factors such as transformation policies. Dave Mars (Cape editor at Business Day) summarized the reasons for shortages of engineering skills as follows, “Failure to market engineering as a career to attract the best students, an investment ‘strike’ on the part of the state during the fiscally austere early 1990s, which caused many engineers to emigrate or change careers, and the overzealous application of affirmative action policies”[10]

Economic reasons

Employment trends and demand for engineering professionals were determined to a large extent by the following significant economic drivers in South Africa during the last three decades: the reduction in agriculture and mining share’s to GDP; and the relative changes within sectors with respect to labour productivity and capital intensity - such as the recessionary period in the construction industry in the 1980s and 1990s, as indicated by Cees Bruggemans, Chief Economist at FNB;[37] Pieter Louw, from PA Louw and Associates;[29] and Dave Marrs, Cape editor at Business Day.[10] This led to an outflow of engineering professionals and artisans to other non-related industries in South Africa as well as to global markets. Presently this has changed. Sustained high economic growth since the 2000s in South Africa fuelled by the unprecedented boom in global commodity prices since 2000, and the government’s committed increase in infrastructure expenditure over the next 5 years are some of the primary causes of South Africa's skills shortages predicament.

37 How new infrastructure could lift growth floor *Sunday Times* 27.05.2007

In the continuation of nonstop growth, SOEs such as Eskom and Transnet increase investment, adding new capacity to rail, port, water and electricity infrastructure, indicated by Deputy President, Phumzile Mlambo-Ngcuka;[38] and Dirk Hermann, Solidarity general secretary.[23] Smaller parastatal such as Airports Company, the water utility, as well as the R20bn plus outlays for the 2010 World Cup, also add to the higher demand for engineering skills.[54]

The government has decided to take the route of a developmental state, meaning that the state is an active promoter of economic growth, by investing heavily in infrastructure in order to enhance economic activity for all. The delivery of services is important so that previously excluded people can get access to the labour market. A strategy like this requires technical skills to work on infrastructure projects and experienced technical managers who can run with and complete projects. This is especially the case for engineering professionals.

Emigration, mobility and the global economy

By all standards, the emigration of highly skilled people and particularly engineering professionals from South Africa is high. Quantifying this trend is not an easy task due to unreliable data and record keeping in this regard. Noticeable is that emigration is usually higher than what is recorded through official SA data (Bhorat Meyer & Mlatsheni 2002). The authors argue that a degree of mobility is necessary if developing countries want to be part of the global economy, but a significant outflow of skilled people can impact on growth and development. This is especially valid for engineering professionals in South Africa, given the current massive investment in infrastructure by government.

There is a very lively global market for skills especially for engineering professionals and it extends further than the developed first world countries. Some examples are the Middle East and the oil states that are magnets for specifically engineering professionals. The South African Navy is losing engineers to the lucrative oil industries of Angola and Nigeria, as indicated by Johannes Mudimu, Navy Chief.[39] In Europe the demographic changes are causing demand for skills – populations are ageing and contracting. The skills market is fluid, engineering professionals can move between industries and they have access to global opportunities. The global industry also offers much higher salaries.

South African based Employment Agencies react on this demand by supplying the wanted skills. The Joint Chief Executive of the Capital Outsourcing Group said the following, “South Africans are in such great demand abroad because: they speak English; are hard working; experienced; multi-skilled; can work in harsh environments; South Africa’s longitudinal position makes it easy in terms of time and money for workers to get to their destinations; and it is easier for locals to get visas for African countries”[40]

38 Asgisa investment leaps forward *Business Report* 23.03.2007

39 Navy losing engineers to African oilfields, but training more *Cape Times*, 23.02.2007

40 Labour Brokers 7 flexible staffing solutions *Star* 30.01.2007

According to SAICE South Africa has lost an estimated 6 000 civil engineers over the past 25 years.[24] The South African Federation of Civil Engineering Contractors confirmed this trend by showing that about a third of SA's engineering graduates over the past 40 years worked abroad.[33]

Lower remuneration than other professions

As indicated in 1.3.6 engineering professionals earn less compared to other professions such as medical doctors and chartered accountants. Lower remuneration as well as an apparent lack of glamour associated with engineering are therefore some of the major factors causing skills shortages in the engineering field. Stakeholders and analysts, such as Ravi Nayagar, chief executive officer at ECSA;[4] Murray and Roberts Cementation;[23] Professor Frank Horwitz, director of the UCT Graduate School of Business;[28] Martin Westcott, MD at P-E Corporate Services;[33] and Webster Ndodana, SAACE's chairman,[41] are convinced that better extensive salary increases can serve as an incentive to save South Africa form engineering skills shortages.

The managing director of Engineering Working Solutions, a recruitment and placement agency in the construction sector, indicated that salary offers for engineering professional in this sector have increased by more than 25 per cent (Interview 2007a). The increase in wages can be an indicator of the demand for certain skills. As indicated in section 1.3.6, industry stakeholders are generally reluctant to provide salary data, and quantitative surveys on the matter are, as a rule, confidential and only available to participants. LFS data for the period 1997-2005 was therefore used to obtain an estimate of remuneration trends for engineering professionals. The data show an average annual increase in engineering technicians' salaries of 8.89 per cent and for engineers and technologists 12.88 per cent over the 8-year period. P-E Corporate Services also reported that the shortage of technical, engineering and manufacturing staff pushed up the salaries for this group compared to other employees. Further evidence in this regard was provided by engineering recruitment and placement agencies as well as related professional organisations (Interview 2007b; Interview 2006d).

Secondary school education

Section 2.2 discusses more fully on the challenge that South Africa faces in terms of secondary education that contributes to the shortages of engineering skills and refers to the strategies applied to try and rectify the problem. Nonetheless, the two most important matters to mention are the low numbers of matriculants who pass Grade 12 with Higher Grade Mathematics and Physical Science (minimum D symbol) qualifying for engineering studies, and the quality of Mathematics and Science knowledge that those students bring with them. In addition to this predicament, it is well known that the engineering field has to compete with other professions such as medicine and commerce to attract

41 Ingenieurs moet na SA terugkom *Beeld* 19.01.2006

potential students from the limited mathematics and/or science pool at matric level.

In terms of shortages of engineering professional and artisans the irony is that the Department of Education is investing close on R1 billion in 06/07 for infrastructure development in schools, but KwaZuluNatal's MEC for Education, Ina Cronjé, warned that there are not skilled people available to put in the plumbing, build the foundations, and lay the cables![42]

Low throughput at higher education institutions

Throughput trends at universities and universities of technology are discussed in detail in section 2.4.3. The most important factor to consider in this section on the reasons for shortages of engineering skills is that the throughput rates to deliver the current average 2 000 graduates at universities and the 3 000 graduates at the universities of technology are far from optimal. This is one of the factors explaining our poor engineer to population ratios with that of comparable countries.

Failure to market engineering as an attractive career

Section 2.3 recounts some of the reasons why potential students do not pursue studies to follow a career in engineering. The EU Commission Report (2006) found that the lack of information was one of the major factors influencing for example women to consider a career in engineering. None of the students interviewed in their *Womeng Project* had any precise information about the job and the actual activities of an engineer. This means that none of them had a good idea of their future career paths as engineers when they started their training. There are many stakeholders that embarked on exceptional initiatives at times to persuade more school learners to pursue engineering as a career. However, it seems that much more has to be done to provide information on engineering in order to market it as an attractive career to attract the best students.

Lack of experiential training opportunities

The lack of experiential workplace opportunities for engineering technicians is a big concern and contributes to the existence of skills shortages. This was explained in Section 1.3.1. Lawless (2005) found in her civil engineering study that about 60 per cent of final-year National Diploma students who responded to her survey in October and November 2004 had not had experiential training and therefore could not graduate. Pierre Blaauw of the South African Federation of Civil Engineering Contractors stated that at the artisan and technician level in the building sector, about 50% of the labour market of about 500 000 do not have access to sufficient training because of sub-contracting practices and the use of temporary staff in the industry.[43]

42 Growing SA's skills *Witness* 25.05.2007

43 Boubedryf kan nie in opbloeitydperk in behoeftes voorsien *Beeld* 19.02.2007

Transformation policies

Migration of white engineering professionals out of the state and parastatal sectors due to transformation policies[51] is frequently put forward as a reason for the engineering skills shortages, as also indicated by Marius Fransman, Transport and Public Work's MEC;[10] Webster Ndodana, president of SAACE;[24] Gareth van Onselen, DA's director of special issues;[44] and Phumzile Mlambo-Ngcuka, deputy president.[45] In general it has been argued that affirmative action has been pursued too aggressively;[46] that it is too costly (according to Ann Bernstein, executive director of the Centre for Development and Enterprises);[47] that it undermines institutions, according to Gareth Onselen, the DA's director of special issues;[44] that we should be basing appointments on competence and not race (Eddie Durant, managing director at Grinaker-LTA);[20] and that we need to debate the impact of employment equity in a mature manner, said Dr Mamphela Ramphele, former managing director of the World Bank (2008). Danai Magugumela, CEO of BKS Consulting Engineers, adds to this that "We need to manage transformation responsibly by recognising and retaining exceptional engineering talent, irrespective of race or gender identity".[19] The South African Institute of Race Relations (SAIRR) found that almost a fifth (one million) of the white population have left the country in the last 10 years, listing crime and affirmative action as the biggest reasons for the exodus[48].

In engineering specifically, ECSA (2008) has pointed to the dangers of pursuing transformation at all costs. In a press release, the council said it obtained an interdict against Tshwane Metropolitan Municipality to stop all disciplinary actions against an engineer who had reported to ECSA that the municipality appointed inexperienced candidates to accelerate transformation. They were appointed as systems operators at the Tshwane Power Control System while they tested poorly prior to their appointment. The engineer believed this posed a danger to public safety as well as to the lives of the systems operators but faced disciplinary action at the municipality after reporting the matter in writing to ECSA. According to ECSA, the Court ruled that it was the duty of a professional engineer to pay due regard to public safety considerations and disapproved of "acceleration of transformation at all costs while disregarding safety consideration" and the Court required "a sensible balance between transformation and safety" (ECSA 2008).

Viv Crone, president of the South African Institute of Electrical Engineering argues that the employment scorecard works against skills development goals.[49] He argues that the scorecard awards companies more points for board and management representivity than for recruitment and training of junior personnel –

44 The public service and affirmative action *SA government: SA Politics* 12.05.2008

45 Who will build the future when the skills dry up? Financial Mail 2005

46 'Get SA out of BEE trouble' *Fin24.com* 07.05.2008

47 Our obsession with job equity could be costing our economy *Daily Dispatch* 18.06.2007

48 Beat the skills trap by employing mentors and mentees *Star* 1 February 2007

49 BEE 'hampers training goals' *The Weekender* 25.03.2007

the emphasis is on senior people and not junior appointments. He suggests that flexibility and creativity be applied to the current system to maximise the resources available. There is also the suggestion that it's not the pull of the private sector that makes engineers leave government, but the push of transformation policies and restructuring (Robert de Neef, engineering professional, 2007).[50]

Whatever the reasons, there has clearly been a large drop in employment of whites in the engineering professions, as indicated by the SAIRR.[51] Our own research shows that the proportion of white engineering professionals employed dropped from 76.9 per cent over the 1996-1999 period to 63.2 per cent over the 2000-2005 period (Figure 1.6 -1.7).

Lawless (2005:251) has suggested that employment equity policies need to be reviewed, particularly in departments which are critically short of engineering staff, and senior staff should be retained post retirement age to initiate and manage projects and train young graduates.

In 2007 an ANC provincial executive member and MEC for Transport and Public Works, Marius Fransman (Fransman, 2007) appealed for a mature and thorough debate on a moratorium on affirmative action in the light of the shortage of engineers. He said:

> One of the unintended consequences of employment equity is the 'leakage' from the economy of white graduates with scarce skills. While employment equity is a strategy to redress historical imbalances, our country cannot afford to lose too many engineers. The question of a possible moratorium on employment equity needs to be thoroughly and maturely debated, based on research into the loss of scarce skills professionals within the context of 'binding constraints' on economic growth and the consequent lack of delivery to the poor. The existence of a 'second economy trap' is arguably the most important historical imbalance that needs to be redressed in South Africa currently. (2007:n.p)

Not surprisingly Fransman's remarks were taken up by opposition parties who subsequently called for a complete moratorium on affirmative action.[52] However, various government ministers, including the Minister of Finance, Trevor Manuel, the deputy President, Phumzile Mlambo-Ngcuka, and the Minister of Labour, Membathisi Madlalana denied the possibility of this happening.

Fransman's appeal was supported, however, by Dr Mamphela Ramphele, former vice chancellor of UCT and a former managing director of the World Bank) (Ramphele, 2008). Speaking at an award ceremony of Masakh' iSizwe Centre of

50 It's not about the money *Mail and Guardian* 19.04.2007

51 White exodus *Citizen* 03.10.2006

52 Parties call for cap on AA, *SAPA* 1.03.2007

Excellence, which awards bursaries to students in the engineering and built environment fields and also has a engineering skills development programme aimed at producing 'engineers with a social conscience', she referred to Fransman's suggestion and said the reaction from some Ministers was to 'shut down the debate'. (Ramphele, 2008:9). She said she was concerned that employment equity was being treated as a 'holy cow'.

> Given the many concerns expressed across the board, and the tough global skills market it is surprising we are not examining the impact of employment equity on our performance as a nation. Are we as much in denial about this as we were about AIDS and Zimbabwe? Why are we not debating this issue in a mature and considered manner? (2008:9)

1.5.4 Impact of skills shortages in engineering

At the macro level engineers are at the core of two key areas of the development enterprise in a country: building and maintaining infrastructure in the public sector; and contributing towards economic growth in the private sector. In the public domain, engineers in the employ of the parastatals have always been involved in the provision of transport, communication and electrification. Those specifically in the civil engineering field are involved in general urban development and upgrading of infrastructure and are by and large employed by local or provincial government. In the private sector engineers are working in a wide range of commercial enterprises including small consulting firms, medium-sized businesses, and large multinational companies. There are also sizeable contingents of engineers who are not working in the traditional engineering sector but are contributing towards sound planning and management in general business. It is therefore very clear that in South Africa a shortage of engineering skills impacts on economic growth in general, and on government's Accelerated and Shared Growth Initiative (ASGISA), which depends on investment in public infrastructure, in particular.

The following excerpts serve as examples of the impact of skills shortages in engineering:

- Testimonies of shortages in civil engineering, of which the seminal report by Lawless (2005) is the most comprehensive and contemporary, indicate that a surge in the supply of engineering professionals in this field is of high priority otherwise the infrastructure investment of government will not be realised and the 2010 World Cup could be at risk.
- Vacant positions at metropole and municipality level – in the metropoles there is a ratio of one civil expert (engineer or technologist or technician) per 21 311 members of the population and only one civil engineer per 60 000 members of the population.[53] The worst hit metropole is Cape

53 Serious skills shortage in engineering field undermines service delivery *Cape Times* 29.01.2007

Town with only one civil engineer per 71 400 members of the population.[50] Lawless (2005) reports that a census of all local and district municipalities and metros showed that of the 231 local municipalities 79 (over a third) has no civil engineers, technologists or technicians. Lawless (2005) indicates further that South Africa is disadvantaged in comparison to other developing nations with regards to the number of people per engineer. Malaysia has 543 people per engineer, Brazil has 227 people per engineer, India 157 people per engineer and South Africa as many as 3 166 people per engineer.

- Local Government Minister Sydney Mufamadi emphasized that the lack of civil engineer professionals at municipal level has a negative effect on service delivery aimed at alleviating poverty in SA.[54]
- Gains in service delivery brought about through Project Consolidate may be lost unless more engineers are attracted to municipalities, according to a report by engineers seconded to struggling municipalities as part of the project launched by Provincial and Local government Minister Sydney Mufamadi. With many of the posts vacant, the engineers seconded to struggling municipalities found that there were no full-time staff to mentor and they were forced to do projects themselves instead of transferring skills.[14]
- Neil Macleod, president of SAICE said, "The South African economy needs municipalities to play their part in ensuring well-constructed and maintained engineering infrastructure if our economy is to achieve the ultimate gross domestic product (GDP) growth target of over 6% a year".[54]
- Shortages in engineering skills lead to project delays, poor quality of workmanship, lack of monitoring and an inferior product/service being delivered, as indicated by engineers seconded to struggling municipalities.[14] Delays in the implementation of projects, further affects the expenditure of the budgets on service delivery, according to Ali Said, infrastructure and engineering business unit manager at the Nelson Mandela Bay municipality.[55] This is already obvious because at municipal level, budgets are not spent.
- Because of bad planning in terms of the demand for skills and the ambitious R95 billion programme to upgrade electricity capacity, power cuts by Eskom occur. Despite an ongoing recruitment drive, Eskom is still short staffed, including engineers.[56] Professor Christo Viljoen, former member of the old Electricity Board, warned that thousands of additional engineers, technicians and operators need to be employed each year at

54 Call for engineers to help municipalities *Business Day* 22.02.2007

55 Bursaries address shortage of skills *The Herald* 19.04.2007

56 Power cuts blamed on skills blackout *STAR* 22.01.2007

Eskom till 2010 and they are just not available.[57] It's not that easy to accelerate the training of engineering professionals.

- Michael McDonald, economic and commercial manager of the Steeling and Engineering Industries Federation of SA, says that engineering skills shortages will definitely hinder potential to double exports.[58]
- According to Productivity SA and the 2007 IMD World Competitiveness Yearbook, South Africa has the world's highest brain drain and worst skills shortages of 55 country studies and its productivity is plummeting and the country ranked last on the availability of engineers.[46]

57 Waar gaan ESKOM nog 1 000 kundiges per jaar kry? *Rapport* 26.01.2006

58 Engineering sector faces hitches *The Star* 19.02.2007

1.6 CONCLUSION

The capacity problem in engineering is a world wide phenomenon, but issues such as migration, equity, lack of experiential training opportunities, shortage of mentors, and the expansion of infrastructure spending further complicate the matter in South Africa.

There was growth in employment of engineering professionals combined (6.97 per cent average annual growth), but the number of engineers and technologists had an average annual growth rate of only 5.91 per cent, while technicians had an average annual growth of 7.65 per cent over the 1996 to 2005 period. Over this period the majority of engineers and technologists worked in the manufacturing and financial and business services sectors. The construction sector is very dependent on the domestic market in which the public sector is dominant. The construction industry went through a slack period, but has picked up over the last couple of years and since 2004 an increase in employment has been reported in this sector. ASGISA will surely stimulate and ensure further growth of this sector the next four to five years and will lead to a demand for employment in especially the public sector. With the current rate of reported skills shortages in the engineering field it will not be easy to fill the current and future vacancies in the public sector.

Progress in racial transformation is visible in employment figures. However, the employment of women engineers, technologists and technicians decreased during the 1996-2005 period and the under-representation of women in the engineering labour market remains an issue. A major shortage of older and experienced professionals is noticed. This has a major impact on the transfer of skills to the younger generation of engineering professionals.

Analysis of data and the investigation of contextual factors show that there is a demand for engineering professionals in the South African labour market. An array of reasons is put forward to try and explain the shortages of engineering skills. These range from socio-economic factors such as economic growth and emigration, educational factors such as poor mathematics education at school and low throughput of engineering students at higher educational institutions, to labour market intervention factors such as transformation policies.

CHAPTER 2

THE EDUCATIONAL CONTEXT FOR ENGINEERING PROFESSIONALS

Against the background of the demand for engineering professionals in South Africa the focus turns to the supply of engineering professionals and the educational context for engineering. The vice-president of ECSA (Interview 2006a) emphasized that it takes about 10 to 11 years to educate and train an engineer, starting in Grade 9 with good Mathematics and Physical Science education at secondary school level and ending when the three years workplace experience is completed. The same principle is valid for engineering technologists and technicians.

It is apparent that engineering graduates enter a profession that has a hallmark of both global competition and global collaboration and we have entered a period where engineering can no longer be considered as anything but a global profession. Higher education institutions are today committed to preparing students to become engineering professionals in the global market. Internationally the research done by the Carnegie Foundation for the Advancement of Teaching (CFAT) on the education of engineers is an example of such an exercise (Sheppard & Silva 2001). Domestically the Centre for Research in Engineering Education (CREE) at the University of Cape Town is the key player in the promotion of engineering education, research and development across the whole country.

This chapter identifies some of the drivers of change in the education of engineering professionals and explores the sufficiency of the skills pipeline for engineering by looking into secondary school education, the reasons for studying engineering, the trends in enrolments and graduations in engineering at universities and universities of technology, the engineering programmes and challenges for institutions offering these programmes and student access and mobility. It also briefly mentions engineering training by FETs and through learnerships.

2.1 DRIVERS OF CHANGE IN THE EDUCATION OF ENGINEERING PROFESSIONALS

There are at least three major drivers of change that have an effect on the education of engineers (Interview 2007b). These are the following: professional and quality requirements; Department of Education; and international accords. A new driver now and in the next four to five years is the ASGISA and JIPSA imperative in terms of scarce and critical skills.

Engineering education is the domain of the profession as well as the higher education institutions and is therefore highly regulated by the Engineering Council of South Africa (ECSA). All the engineering programmes are accredited by ECSA. The Engineering Standard Generating Body (ESGB) plays an important role in setting up qualifications and ECSA (by law) accredits all programmes. The engineering programmes and the process of accreditation are discussed in more detail in section 2.5.

The Department of Education is the second driver in terms of the national imperative of access, throughput and articulation. Selection for access to engineering programmes at higher education institutions is almost exclusively based on potential students' results in Mathematics and Physical Science in the final matriculation exam. Up to now the quality of teaching in these subjects as well as the small number of learners passing matric with the required symbols posed major challenges for the education of professional engineering students. In 2005 only 39.94 per cent of matriculants who passed higher grade Mathematics passed with a C symbol or higher and only 23.14 per cent of matriculants who passed Physical Science at higher grade passed with a C symbol or higher (Department of Education 2005). Higher grade C is regarded as the minimum standard in Mathematics in order to follow an engineering programme at all, except two universities, which require higher grade D. The new Mathematics curriculum and the question whether it will provide an adequate foundation for engineering programmes adds to this challenge. The articulation between programmes is also a topic of concern. Access and the mobility of engineering students are discussed in more detail in section 2.5. In terms of throughput rates the low output of engineering graduates forces the engineering education institutions to try and change this trend – throughput trends are discussed in more detail in section 2.4.3.

International accords are another driver of change. The Washington Accord is a system of mutual recognition of graduate engineering qualifications across a group of countries including the UK, USA, Australia, New Zealand, Hong Kong, Canada and Ireland. This agreement recognizes the substantial equivalency of programs accredited by these countries, and recommends that graduates of accredited programs in any of the signatory countries be recognized by the other countries as having met the academic requirements for entry to the practice of engineering. The Washington Accord was signed in 1989. This has been followed by the Sydney Accord in 2001 which applies to technologists and the Dublin Accord in 2002 for technicians.

There is also a Deans' Forum that was formed by the International Council for Research and Innovation in Building and Construction (CIB) where deans (leading faculties of a number of departments covering teaching and learning and research that embrace architecture, civil engineering, planning or construction disciplines) can work together on two aspects of international accreditation: integrating accreditation across disciplines within countries; and integrating and coordinating multiple accrediting bodies operating internationally across countries.[59] The goals of improving consistency of standards, approach and improving effectiveness of resourcing for universities and professional

59 Launch CIB Deans' Forum *CIB News Article* 14.06.2007

institutions were seen as drivers for the Deans' Forum. The ambition of the Deans' Forum is to move over time towards principles of the Washington Accord in engineering accreditation.[59]

A new driver now and in the next four to five years is the ASGISA and JIPSA imperatives in terms of scarce and critical skills. It is a world-wide trend that the lack of engineering capacity is hampering development. The shortage of engineering skills in South Africa is specifically seen as one of the worst capacity and scarce skills crisis in years. South Africa is currently in a period of extensive expansion of state expenditure, particularly in infrastructure. JIPSA has requested higher education institutions to increase their delivery of graduated engineering professionals. To date there are no formal arrangements between JIPSA and higher education institutions, except for the R20 million monetary contribution to some of the institutions to try and increase the number of engineering graduates. However, this seems difficult against the background of the low number of matrics with Higher Grade Mathematics and Physical Science from which the engineering faculties can source potential students and the low throughput rates of graduates at universities and universities of technology in engineering programmes.

2.2 SECONDARY SCHOOL EDUCATION

A universal problem for the engineering profession across the world is the quality of school Mathematics and Physical Science. In South Africa there are two important considerations, interrelated but distinct: the numbers of matriculants who qualify for engineering, and the quality of Mathematics and Physical Science knowledge that those students bring with them (Case 2006). To prepare learners for matric, a good education system with enough properly qualified teachers from grade one up to matric level is required. High-quality engineering students come from good schools with good quality Mathematics and Physical Science teachers (Interview 2006f).

To study engineering at university, a higher grade Mathematics symbol of A, B or C is required and for most universities of technology a minimum of C-symbol standard grade Mathematics is required. These criteria present a challenge. Of the 169 026 candidates that passed Mathematics in 2005, 32 112 (19.00 per cent) passed at higher grade. Among those that passed Mathematics at higher grade in 2005, only 4 210 (13.11 per cent) passed with an A symbol, 3 302 (10.34 per cent) passed with a B symbol, 5 296 (16.49 per cent) passed with a C symbol, and 6 342 (19.75 per cent) passed with a D symbol (Department of Education 2005). The education department aims to double the number of matriculants with passes in Mathematics on higher grade to 48 000 within the next couple of years. Considerably fewer candidates write Physical Science. In 2005 only 45 652 (35.29 per cent) passed Physical Science on the higher grade. Among those that passed Physical Science at higher grade in 2005, only 3 051 (6.68 per cent) passed with an A symbol, 2 811 (6.16 per cent) passed with a B symbol, 4 703 (10.30 per cent) passed with a C symbol, and 7 536 (16.51 per cent) passed with a D symbol (Department of Education 2005).

It is well known that the engineering field has to compete with other professions such as medicine and commerce to attract potential students from the limited Mathematics and/or Science pool at matric level. Jawitz, Case & Tshabalala (2000) found in interviews with the pool of suitable qualified women students at UCT that their preference was for medicine as an initial choice, with a strong attraction of students towards commerce. Only women students, who decided to pursue B.Sc. degrees, thought that they may also consider engineering as a study field.

Furthermore, to prepare learners for matric, a good education system with enough properly qualified teachers from grade one up to matric level is required. The Third International Mathematics and Science Study (TIMSS), which was carried out in 1995 and 1998 suggested that levels of Mathematics and Science literacy are particularly low in South African schools. It was widely reported that South Africa came last in the group of international participants in this study. Howie (2005) found that language seems to be a critical influencing factor, and also highlighted the importance of other classroom and socio-economic variables. Studies like this show that quality problems in terms of Mathematics achievement are systemic.

Case (2006) warns that in the light of this existing scenario, early reports on the implementation of the new FET curriculum are alarming. It is reported that teachers only received a total of five days of orientation during 2005 to prepare for the new curriculum to be implemented in 2006. This involves a new Mathematics curriculum which is seemingly similar to the former Higher Grade curriculum, and a completely new subject, Mathematics Literacy.

Another relevant curriculum development for engineering at secondary school level is that the subject of Technology, which had been recently introduced at junior secondary level, has now been removed from the school curriculum (Case 2006). Some of the tertiary training institutions highlighted the contribution of the subject Technology towards improving technological literacy amongst the population, a useful foundation to studies in engineering (Reed Case Linder & Ingerman 2005).

Since the late 1980s students from disadvantaged schooling backgrounds started to have access to privately funded extra-curricular initiatives in Mathematics and Science. These include initiatives of institutions such as the Science and Industrial Learnership Initiative (SAILI) and the Programme for Technological Careers (PROTEC) - a national independent non-profit educational service provider in South Africa that specialises in Mathematics, Science and Technology education and provides educator based training and learner based education.

A host of other Saturday schools, afternoon tutorials, or vacation time projects are also trying to improve the mathematics and science pool of learners. However, it seems that there is no systematic investigation into the collective impact of these projects, but it has been anecdotally reported that most of the engineering students from former Department of Education and Training (DET) schools have been involved in at least one of these initiatives (Case 2006). Case argues that the engineering profession needs to get more involved in schools, to make any relevant contributions it can towards improving mathematics and science teaching, and also in encouraging learners to take up careers in engineering.

A World Bank report (2007) described potential initiatives that were being implemented in developing Asian countries where high school children were given monetary incentives to study Mathematics and Science in matric.

The National Research and Development (R&D) Strategy (2002) recognises that human resource development in science and technology is not being adequately developed and renewed. The strategy proposes a highly targeted approach towards increasing excellence in Mathematics and the Sciences among black matriculants and young women. New Centres of Excellence are being established to attract young people to sustainable careers in scientific research. Special programmes for the promotion of women in science have also been proposed.

2.3 REASONS FOR STUDYING ENGINEERING

Encouraging more students to take up careers in engineering is not an easy task. The underlying reasons behind career choices are complex. Engineering is not always the exclusive choice of an individual and in many instances it is found that their families have influenced them. The EU Commission Report (2006) reveals that the level of education of the two parents of women engineers has an important influence on their choice of engineering as a study field and career; even more so if they have engineers in their family or close environment. A number of other studies also emphasise the positive effect of a role model on choosing engineering (Carter & Kirkup 1990; Coles 1994; Smith & Erb 1986).

Jawitz and Case (1998) investigated the reasons given for studying engineering by a first year cohort across the Western Cape. The results were disaggregated according to race and gender. The study showed that financial incentives were mentioned across all groups with no significant differences between them. White men students made strong mention of practical engineering activities and problem-solving. White women students appeared to be strongly motivated by school experiences and by supportive family environments, while black men and women students seemed to be motivated by opportunities to serve their communities and to prove themselves in careers historically dominated by white men. This latter finding was further supported by a later series of studies amongst mechanical engineering students at UCT (Reed & Case 2003).

The EU Commission Report (2006) found that the lack of information was one of the major factors influencing women to consider a career in engineering. None of the students interviewed in their *Womeng Project* had any precise information about the job and the actual activities of an engineer. This means that none of them had a good idea of their future career paths as engineers when they started their training. Usually training institutions that offer engineering studies have information policies and events to inform potential students about the course. The Report mentions that getting information through personal contact seems to be a decisive factor.

With regard to encouraging more students to take up careers in engineering, again there are no simple solutions. The experience of the civil engineering profession is instructive in this regard. Following periods with low student numbers, they have embarked on unprecedented initiatives to draw in more school learners. There have recently been some increases in the numbers of civil engineering students but it is not clear whether this can be attributed to these initiatives or whether it is maybe more as a result of the general economic upturn (le Roux 2006).

2.4 TERTIARY ENGINEERING EDUCATION: THE SUPPLY OF ENGINEERING PROFESSIONALS

In 2005 the enrolment ratios between humanities (including education), business and commerce and science, engineering and technology were 49%: 26%: 25% (Bot 2007). The recent National Plan for Higher Education (2001) proposes a shift of enrolments over the next five to ten years more towards the Science, Engineering and Technology (SET) fields. The goal sets ratios of 40%: 30%: 30% respectively. Following the ASGISA initiative, there is anecdotal talk of universities being asked by the government to dramatically increase the size of their engineering faculties. However, it should be taken into account that the pool of potential candidates for higher education institutions hasn't increased sufficiently, especially in respect of those with Higher Grade passes in Mathematics and Physical Science.

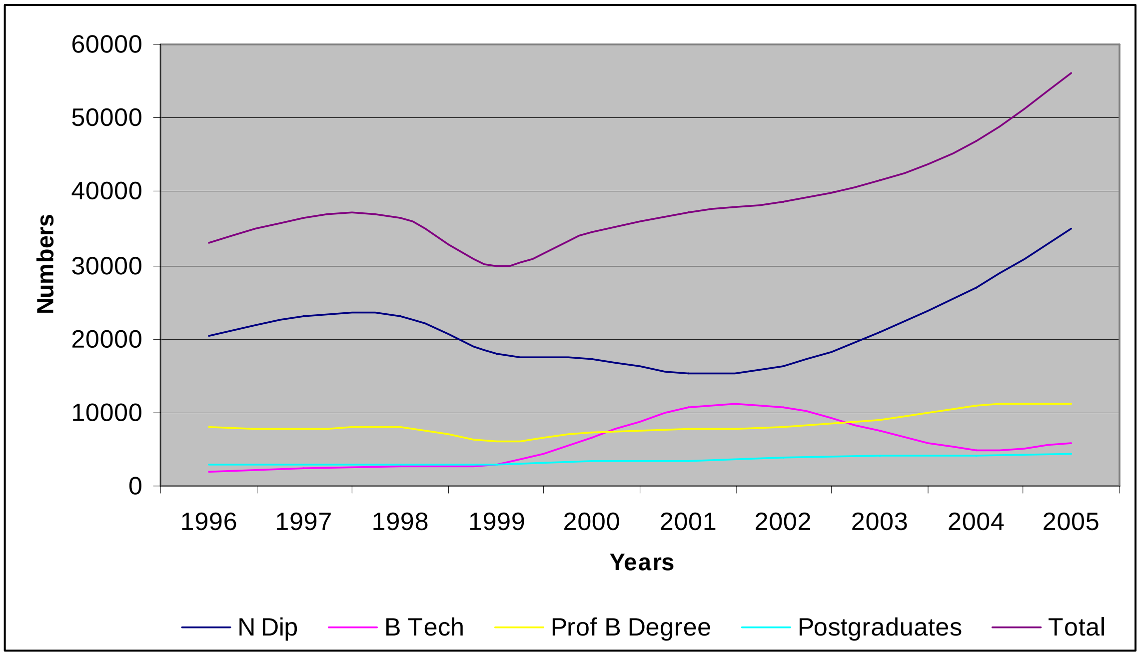
In discussing the supply of engineering professionals, first enrolments will be looked at, then graduations and then also throughput at universities and universities of technology. Transformation in the supply of engineering professionals will also distinguish between enrolment by race and gender and graduations according to race and gender.

2.4.1 Enrolment trends at universities and universities of technology

Regarding career choice there has been a insignificant change in the number of students taking up engineering studies at universities in comparison with the dramatic increase in those studying towards an engineering qualification at the universities of technology, specifically at the B Tech level (13.85 per cent average annual growth over the 1996 to 2005 period), as it started off from a low base (1 840 enrolments in 1996). Enrolment for the N Dip is, however, still the highest (34 874 in 2005) and postgraduate enrolments the lowest (4 276 in 2005) (see Figures 2.1). Enrolments for the Prof B Degree increased with only 3.92 per cent over the 1996 to 2005 period (Table 2.1).

The drop in enrolments between 1998 and 2002, specifically for students at the technician level, was mainly the result of the fact that the public sector has not offered bursaries over that period in areas such as electrical engineering (Interview 2007b).

Figure 2.1 Engineering enrolment, 1996-2005



Source (DoE 2005)

Enrolment data obtained from the DoE and ECSA differ to some extent, as shown in Table 2.1, because the DoE includes some fields of study under engineering which are excluded by ECSA. DoE data also includes engineering fields of study such as Graphic and Drafting; Engineering Mechanics; and Engineering Science which are excluded by ECSA. ECSA includes only nine main fields of study: Aeronautical, Agricultural, Chemical, Civil, Electrical, Industrial, Mechanical, Metallurgical and Mining engineering. DoE in addition to the nine main fields of study, also gives a breakdown according to Automotive engineering; Bio-engineering; Computer engineering; Environmental engineering; Geological engineering; Instrumentation; Manufacturing engineering; Marine engineering; Materials engineering; and Surveying and Mapping which are sub-fields of study under ECSA's nine main fields of study.

Table 2.1 Average annual growth rate in undergraduate engineering enrolment, 1996-2005

Undergraduate	Source	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	% Average annual growth
Engineer enrolment	HEMIS	7895	7850	7967	6050	7188	7656	8135	8901	10886	11159	3.92
	ECSA			8014	5548	6524	6845	7166	7861	8613		
University of Technology enrolment	HEMIS	22265	25691	25564	20831	23904	25908	26760	28538	31772	40784	6.96
	ECSA			21984	13944	16774	19586	18090	20814	28690		
Technician enrolment	HEMIS	20426	23188	22965	17993	17270	15231	16157	20926	27033	34874	6.12
Technologist enrolment	HEMIS	1840	2503	2599	2838	6635	10676	10603	7612	4739	5910	13.85
Total	HEMIS	30160	33541	33531	26881	31092	33563	34895	37439	42657	51944	6.23
	ECSA			29998	19492	23298	26431	25256	28675	37303		

Source (DoE 2005; ECSA 2008)

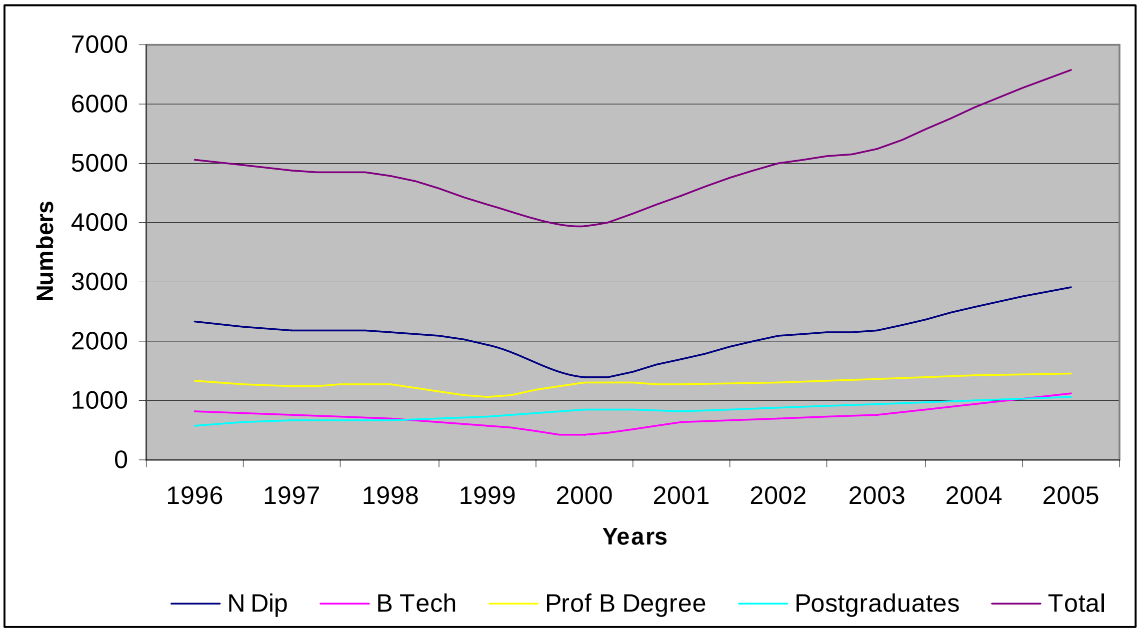
Note: DoE data includes engineering fields of study which are excluded by ECSA, such as Graphic and Drafting; Engineering Mechanics; and Engineering Science

2.4.2 Graduation trends at universities and universities of technology

There has only been a marginal increase in the absolute number of engineers graduating from universities and technologists and technicians graduating from universities of technology between 1996 and 2005 (see Figure 2.2 and Table 2.2).

In 2005 there were a total of 6 568 graduates (under- and postgraduate) in engineering of which only 16.18 per cent (1 063) were postgraduates. Among the 5 506 undergraduates in 2005, 52.85 per cent (2 910) were N Dip graduates, 26.63 per cent (1 130) were B Tech graduates and 20.52 per cent (1 466) were Prof B Degree graduates.

Figure 2.2 Engineering graduations, 1996-2005



Source (DoE 2005)

The average annual growth rate for undergraduate engineers, technologists and technicians, were only 1.00, 3.73 and 2.50 per cent respectively over the 1996 to 2005 period (Table 2.2). The annual output of engineering professionals has remained almost static, despite the increasing demand for engineering services and replacement of engineering professionals that are retiring from the workforce.

Graduation data from the DoE and ECSA differ to some extent, because the DoE includes some fields of study under engineering which are excluded by ECSA. DoE data also includes engineering fields of study such as Graphic and Drafting; Engineering Mechanics; and Engineering Science which are excluded by ECSA. ECSA includes only nine main fields of study: Aeronautical, Agricultural, Chemical, Civil, Electrical, Industrial, Mechanical, Metallurgical and Mining engineering. DoE in addition to the nine main fields of study, also gives a breakdown according to Automotive engineering; Bio-engineering; Computer engineering; Environmental engineering; Geological engineering; Instrumentation; Manufacturing engineering; Marine engineering; Materials engineering; and Surveying and Mapping which are sub-fields of study under ECSA's nine main fields of study.

The sharp drop in the number of technician graduations between 1998 and 2002 can be related to the difficulty that students experienced in getting access to bursaries and finding industrial placements for their experiential training year (Interview 2006b). Employment agencies contribute to this dilemma by placing technicians and technologists for short periods at different employers. This implies that they don't get the opportunity to work at one employer for the required period of time in order to complete their experiential training and obtain their qualifications (Interview 2006b; Interview 2006d). Lawless (2005) found in her civil engineering study that about 60 per cent of final-year National Diploma students who responded to her survey in October and November 2004 had not had experiential training and therefore could not graduate. Some of the reasons put forward to explain this trend are: Employers' concern regarding the quality of the training of students; the location of some universities of technology that poses a problem in terms of access to employers, because many students do not have the financial means to travel to centres to look for work; limited assistance by universities of technology to find job opportunities for students; resistance of businesses to employ inexperienced students and call for candidates to have at least five years work experience; and the revision of labour laws adding to the resistance of businesses to take on employees who can't add immediate value to their organisations. Lawless explains the necessity of the conversion of the national diploma in civil engineering to a learnership. This is necessary to ensure that industry is compensated for its involvement in training.

Table 2.2 Average annual growth rate of undergraduate engineering graduations, 1996-2005

	Source	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	Average annual growth
		N	N	N	N	N	N	N	N	N	N	
N Dip graduations	HEMIS	2330	2189	2140	1947	1385	1710	2104	2196	2564	2910	2.50
B Tech graduations	HEMIS	812	756	691	564	433	641	687	772	952	1130	3.73
Total: University of Technology	HEMIS	3143	2945	2831	2511	1817	2350	2791	2968	3517	4039	
	ECSA			2341	1404	1292	1814	1956	2284	3160		
Prof B Degree graduations	HEMIS	1341	1243	1277	1051	1292	1286	1306	1354	1424	1466	1.00
	ECSA			1226	995	1235	1274	1691	1305	1177		
Total	HEMIS	4483	4188	4108	3562	3109	3636	4097	4323	4941	5506	2.31
	ECSA			3567	2399	2527	3088	3647	3589	4337		

Source (DoE 2005; ECSA 2008)
Note: DoE data includes engineering fields of study which are excluded by ECSA, such as Graphic and Drafting; Engineering Mechanics; and Engineering Science

2.4.3 Throughput trends at universities and universities of technology

The throughput rates in order to supply 1 466 engineering graduates at universities and the 4039 engineering graduates at the universities of technology are very poor. If you consider that the B.Sc. (Eng.) is designed to take four academic years, the National Diploma three years, and the BTech one additional year after the National Diploma, it is clear that throughput rates are far from optimal. In order to determine throughput, enrolments are compared to graduations three and four years later. Although this method is useful from a comparative point of view, it is not a precise measurement as first-year enrolments will include those who are repeating, and final-year graduations will include those who are graduating after five or more years of study. Figures 2.3

show the throughput trend for first-time entering engineers, Figures 2.4 for first-time entering technologists, and Figures 2.5 for first-time entering technicians.

The throughput of first-time entering engineers qualifying at universities has stayed static at about 60 per cent between 1999 and 2005. For first-time entering technicians the average throughput rate over the same period was only 40 per cent and for first-time entering technologists about 55 per cent. According to Lawless (2005) there are a few factors that can contribute to the low throughput rates. These factors include the following: previously disadvantaged learners were encouraged to enter tertiary education without applying and enforcing entrance criteria; learners who entered had poor grounding in Mathematics and Physical Science and lacked efficiency for the language of instruction; not all institutions were ready to offer supplementary or bridging courses to prepare these learners for tertiary education; the increase in enrolments caused problems in terms of the size of classes and extra staff were taken on with inadequate qualifications; black students struggle to afford tertiary education unless they obtain loans or bursaries, and when they try and fund themselves problems occur; and the biggest drop out takes place at the universities of technology where students are required to do workplace training before qualifying – sufficient opportunities are not always available. Students at the universities of technology reported that they find it difficult to find industrial placements for their experiential training year. Students are only awarded the National Diploma after completion of this training as well as four semesters of academic work, and it appears that many students are unable to complete the diploma for lack of this work experience. With the economic pressures on companies, together with a shortage of experienced professionals, they seem to be less willing to take on personnel that require training such as in-service trainees from the universities of technology.

Higher education institutions are trying to address the poor throughput rate by applying the following strategies (Interview 2007b; Lawless 2005):

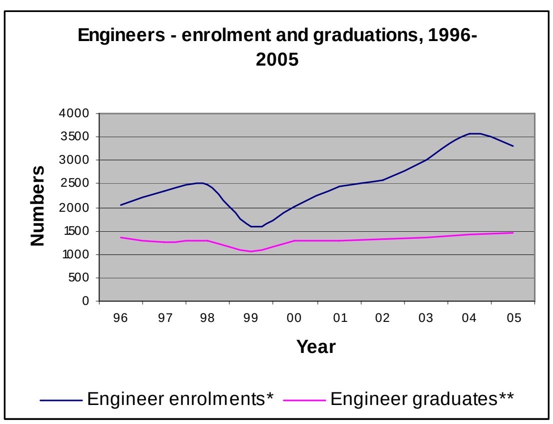
- Rigorous entrance criteria - some of the universities that achieve the highest throughput rates are known to apply the most stringent entrance criteria and procedures.
- Dedicated foundation or bridging programmes and extended programmes - institutions established foundation programmes to help students to deal with the challenges of tertiary education. Some universities decided to extend the engineering programme by converting the four-year degree to a five-year degree.
- Funding – many students do not have the financial means to afford training at a higher education institution. In these instances the institutions strive to assist the students to obtain loans and bursaries.
- Monitoring and support – support is given by means of supplementary lessons, assigning a senior student as a mentor to the student, provide students with life skills training.

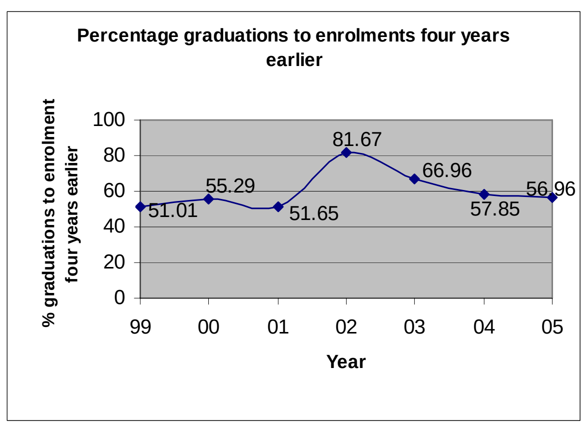
- Introducing students to young graduates as role models – students are encouraged to communicate with young graduates and to join professional associations in order to obtain access to people who can provide them with advice.
- Appointing more lecturers - in some institutions the staff to student ratios were too low because of an increase in enrolments. Additional staff is then appointed.
- Upgrading of the qualifications of lecturers especially at universities of technologies.

Maree, Pretorius & Eiselen (2003) noted that engineering students who perceive their environment to be supportive, who know where to find help, and who do not struggle with the language of Mathematics, are more likely to be successful. Pitt (2002) declared that students in higher education need an assortment of strengths, including motivation to be successful in their studies.

The JIPSA business plan (2006) suggested that the supply of engineering professionals could be increased by an additional 1000 per annum. They came to this conclusion after a consultation process with Deans of the Faculties of Engineering and the Built Environment at universities. JIPSA is expecting that the output in the form of registered professionals will increase by 1000 over and above current output without a significant increase in the inputs. The 1000 target could include other construction related professions such as construction and project management, quantity surveying, and architecture.

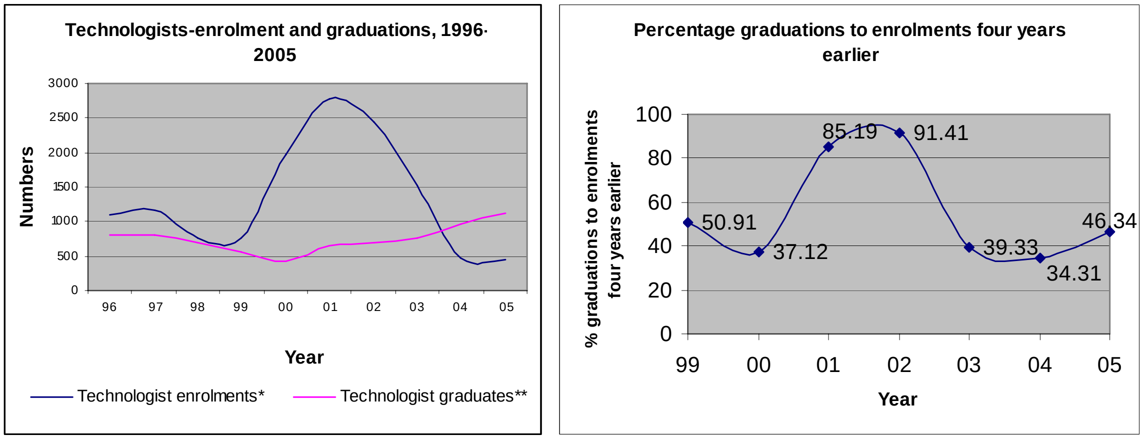
Figure 2.3 Throughput trend for first-time entering engineers





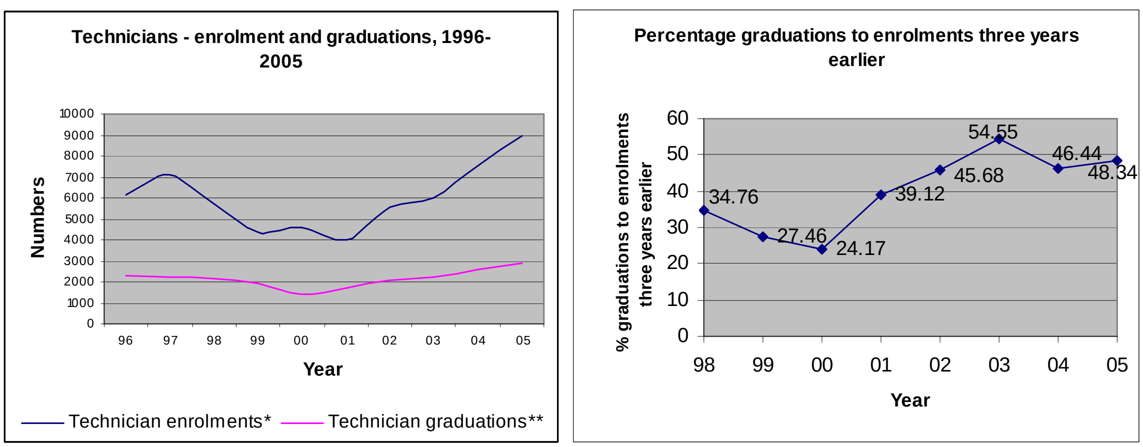
Source: DoE 19960-2005
* First-year enrolled ** Graduation four years later

Figure 2.4 Throughput trend for first-time entering technologists



Source: DoE 19960-2005
* First-year enrolled
** Graduation four years later

Figure 2.5 Throughput trend for first-time entering technicians



Source: DoE 1996-2005
* First-year enrolled
* Graduation three years later

2.4.4 Graduation trends in different engineering disciplines at universities and universities of technology

Table 2.3 reports the graduation trends for engineering disciplines at universities and universities of technology over the 1996 to 2005 period. A table disaggregating engineering discipline data for engineers, technologists and technicians, according to both under- and postgraduates are shown in Annexure A. There was an improvement in engineering graduations in a couple of disciplines between 1996 and 2005. One of the factors contributing to a shortage in graduations in certain scarce disciplines is the fact that tertiary institutions are struggling to retain quality teaching and research staff in disciplines that compete with demand in the private sector (Interview 2006h).

Table 2.3 Graduation trends in engineering fields of study, 1996-2005

Fields of study	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	
Undergraduates											
Electrical	1412	1317	1349	1157	971	1164	1348	1517	1666	1890	3.30
Civil	725	648	683	694	639	674	731	720	875	898	2.40
Mechanical	803	754	702	524	453	603	587	610	616	743	-0.86
Chemical	496	422	459	305	437	516	498	541	664	640	2.87
Industrial	347	397	264	197	154	201	208	233	309	372	0.77
Metallurgical	137	95	102	78	85	108	77	100	111	196	4.03
Mining	125	142	172	99	42	39	47	53	65	156	2.49
Surveying	116	110	81	108	83	68	67	75	69	83	-3.60
Materials	71	78	98	66	38	50	68	65	83	79	1.21
Computer	44	45	97	0	4	3	45	88	139	112	10.88
Engineering Mechanics	0	0	0	60	67	14	131	63	101	85	*5.82
Marine	13	7	26	16	13	25	36	49	51	50	16.15
Graphics	0	0	0	75	10	1	21	29	29	60	*-3.77
Aerospace	83	54	13	5	4	4	7	11	16	9	-21.87
Bio-engineering	0	0	0	0	0	52	69	64	10	9	**-36.42
Agriculture	29	31	15	17	16	17	21	21	16	19	-4.82
Environmental Engineering	0	0	0	24	26	32	27	34	29	11	*-12.38
Manufacturing	0	0	0	16	17	8	18	4	0	16	*0.53
Engineering Science	0	0	0	3	0	0	27	3	3	0	0
Instrumentation	0	0	0	6	0	0	1	1	0	0	0
Automotive	0	0	0	3	0	0	0	0	1	2	*-8.91
Geological engineering	0	0	0	1	0	0	0	0	0	0	0
Other Engineering & Engineering Technology	83	88	47	109	51	59	64	44	90	79	-0.57
Total undergraduates	**4483**	**4188**	**4108**	**3562**	**3109**	**3636**	**4097**	**4323**	**4941**	**5506**	**2.31**
Postgraduates											
Total postgraduates	**576**	**682**	**673**	**728**	**842**	**826**	**892**	**932**	**998**	**1063**	**7.05**
Total	**5059**	**4870**	**4781**	**4289**	**3951**	**4463**	**4989**	**5255**	**5939**	**6568**	**2.94**

*** 1999-2005**

**** 2001-2005**

Source: DoE 1996-2005

Although small (3.30 average annual growth), the growth in electrical engineering graduations over the 1996 to 2005 period is encouraging seen against the expansion plans of Eskom in building new power stations and the reported shortages in municipalities.

Graduations in civil engineering experienced an average annual growth of only 2.67 per cent over the 1996 to 2005 period. This low growth may not be sufficient, given the huge capital investment in infrastructure by the government.

A major beneficiary of this is construction in general, and civil engineering in particular. It will take some years for the South African construction industry to overcome its current skills shortages in this sector. The specialised skills pool of bridge-building in South Africa has for example been severely depleted, as several experienced bridge engineers have been lost to emigration and retirement, according to Pieter Louw of PA Louw and Associates.[29]

The automotive industry is the third-largest and most expanding sector in the South African economy,[60] but there was negative growth in automotive and mechanical engineering graduations over the 1996 to 2005 period. Mechanical engineers are required in most sectors of the economy and especially in the automotive industry (Interview 2006g; Interview 2006h). The low number of graduations of automotive technologists and technicians is very discouraging, and this fact needs to be addressed if the South African automotive industry wants to continue focusing on further improvements in competitiveness in terms of production and quality, according to Nico Vermeulen, the director of the National Association of Automobile Manufacturers of South Africa (NAAMSA). 'Component manufacturers ideally require high local content and high-volume domestic production to grow the automotive industry' according to Dr Justin Barnes, MD of consultancy Benchmarking and Manufacturing Analysts.[61] It is fortunate that NAAMSA is planning programmes to increase technical/autotronics and commercial skills development in the automotive industry.[61] The Nelson Mandela Metropolitan University also started a B Engineering degree in Mechatronics.

The positive growth in chemical engineering graduations over the 2000 to 2005 period after a decline over the 1996 to 1999 period is encouraging, given that chemical engineering is very versatile and chemical engineers can be employed as petroleum engineers, metallurgical engineers or in the minerals and mining industry. Petronet aims to be the foremost operator and maintenance partner for all future liquid fuel and gas pipelines and related facilities in southern Africa (Department of Public Enterprises 2006). Furthermore, an upturn of activity in the southern African offshore oil and gas industry has increased demand for specialised offshore services that are essential to overall safety and integrity.[62] With forthcoming environmental legislation and new emphasis being placed on environmental protection in South Africa more graduations in environmental engineering will be necessary.[63]

The increase in mining and metallurgical engineering graduations could be attributed to the growing availability of bursaries in this field, especially for black students (Interview 2006h). Historically, the gold mining industry has been a

60 Auto industry prospects for 2006 *Engineering News* 10.03.2006

61 When MIDP ends, will South Africa still have an auto industry? *Engineering News* 17.03.2006

62 Specialised services are in great demand *Engineering News* 10.06.2005

63 Engineered technology division well positioned for new business *Engineering News* 26.11.2004

significant employer of engineers, but employment levels have decreased substantially in recent years.

The number of computer engineering graduations grew from 44 in 1996 to 112 in 2005, but it is still difficult to find computer engineers with the right skills, especially with security, Internet protocol telephony and wireless networking skills.[64] According to ASGISA, electronic communications will be one focus of priority attention in growing South Africa's broadband network; in completing a submarine cable project to provide international access; and in establishing telecommunications, especially in the rural areas of the country (SA Government Information 2006). According to research findings by the Industrial Development Corporation (IDC) the demand for networking skills outstrips supply by far.[64]

The negative growth in agricultural engineering graduations is a concern in a country like South Africa where agricultural engineering can contribute to increased productivity to address food shortages and job creation (Berry 2006).

The positive growth (9.05 average annual growth over the 1997 to 2005 period) in aerospace / aeronautical engineering graduations from universities is encouraging (see Annexure A) in light of the expected doubling in the number of air passengers in the next 10 years and its tripling within 15 years.[65] The South African Minister of Public Enterprises has commented on the government's keenness to make South Africa a centre for aerospace manufacturing.[66] However, the same positive trend is not noted for aerospace / aeronautical technologist and technicians. There is a shortage of aeronautical technicians in the air force and unqualified technicians have to stand in and do the work of qualified aeronautical technicians.[67] The decrease in graduations for aeronautical technical courses is thus disappointing.

According to Professor Ricardo Hausmann, a Harvard University economist,[68] South Africa needs to generate jobs in the export-orientated manufacturing sector to make growth sustainable, as declines in most developing countries' growth coincided with collapses in exports. He argues that economic growth based on growth in the construction sector is an unsustainable strategy. The decline in manufacturing engineering graduations is thus disappointing.

64 SA needs 70 000 techies *Citizen* 7.07.2006

65 SA's Airbus designer tells how he started with just a matric *Daily Dispatch* 24.03.2006

66 Investment in technology key to competitiveness *Engineering News* 2.06.2006

67 Lugmag: Tegnici 'nie opgelei', herstelwerk maak vliegtuie 'tydbomme'' *Burger* 17.03.2006

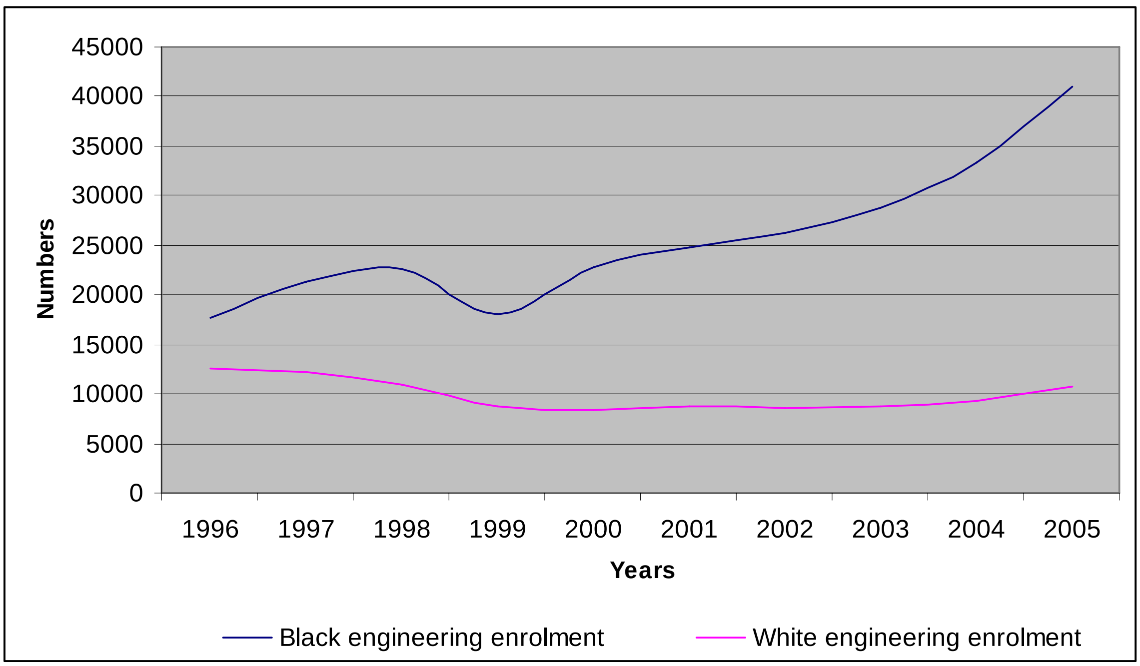
68 Export-oriented manufacturing key to meeting SA growth target - Harvard economists *Engineering News* 11.08.2006

2.4.5 Transformation

Enrolment

The democratization of South Africa introduced a dramatic transformation in the student intake at historically white higher education institutions. The increase in the proportion of *enrolment* (for National Diplomas, B Technology, Professional B Engineering degrees) of black engineering students - comprising African, coloured and Indian students - compared to white students is prove of this as shown in Figures 2.6 and 2.7 and Table 2.4. A breakdown by race for postgraduate engineering enrolment is not given, because the numbers are too small.

Figure 2.6 Undergraduate engineering students' enrolment according to race, 1996-2005

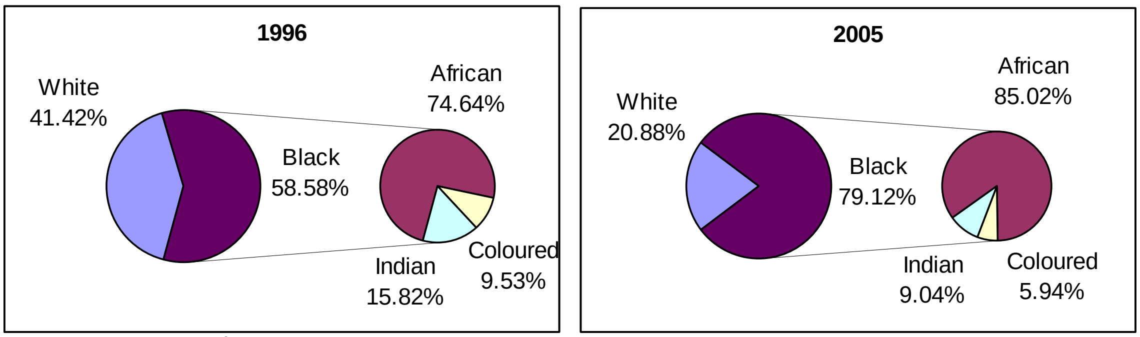


Source (DoE 1996-2005)

The enrolment of undergraduate black engineering students more than doubled over the 1996 (17 666 black students) to 2005 (41 076 black students) period, indicating an average annual growth of 9.83 per cent over this period. In comparison the enrolment of white engineering students decreased with an annual average of 1.57 per cent – there were 12 494 white students enrolled in 1996 and only 10 840 white students 9 years later in 2005. Disaggregating the black group shows that the average annual growth rate of enrolments for Africans was the highest – 11.43 per cent for African engineering students compared to 4.20 per cent for coloureds and 3.20 for Indians.

Proportionally, enrolment of black engineering students constituted just more than half (58.58 per cent) of total engineering enrolments in 1996 compared to more than three quarters (79.12 per cent) in 2005. Figure 2.7 shows the proportions of the disaggregated black group. In 1996 African engineering students comprised 74.64 per cent of the group and this figure increased to 85.02 per cent in 2005.

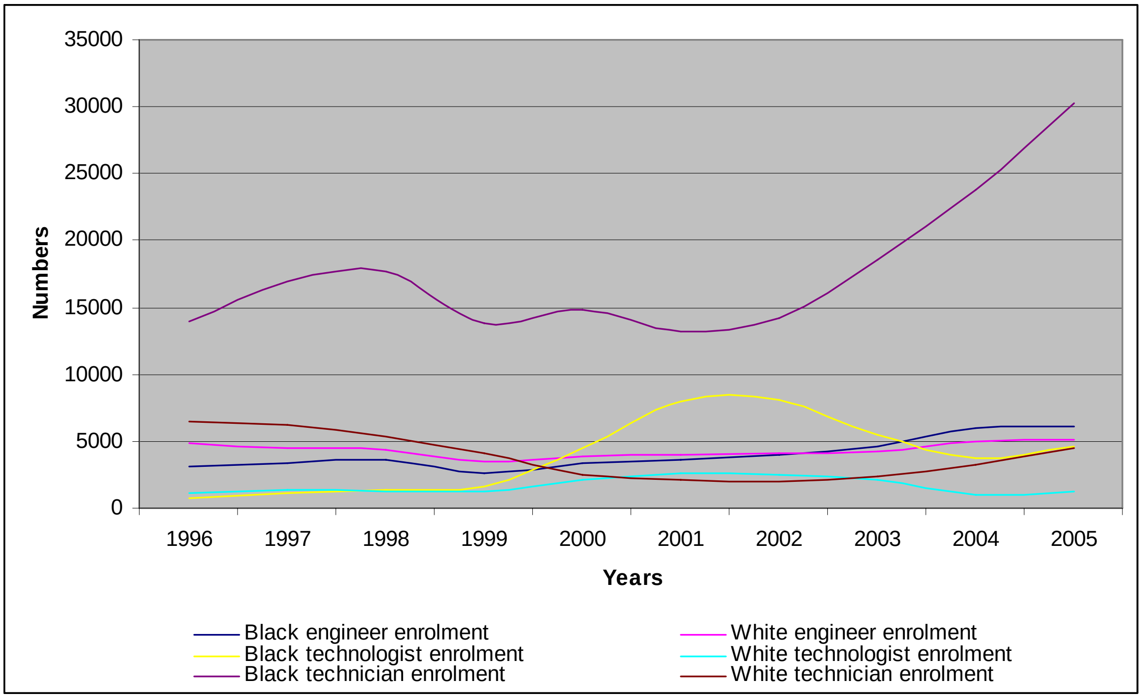
Figure 2.7 Enrolment proportions of undergraduate engineering students, according to race, 1996 and 2005



Source: DoE 1996 and 2005

Figure 2.8 shows the undergraduate enrolment trends separately for black engineer, technologist and technician students and Figure 2.9 the enrolment proportions. The enrolment of black engineer students almost doubled from 1996 (3 077 black engineer students) to 2005 (6 081 black engineer students), indicating an average annual growth of 7.86 per cent over this period. There was practically no growth (average annual growth of 0.55 per cent) in the number of white engineer enrolments over this period. In 1996 enrolment of black engineer students constituted more than a third (38.98 per cent) of all engineer students compared to more than half (54.57 per cent) in 2005. The disaggregated black group shows that in 1996, 59.40 per cent of this group was African, while in 2005 this figure increased to over two thirds (64.98 per cent) – 1 825 African students in 1996 compared to 3 951 in 2005.

Figure 2.8 Undergraduate enrolments of engineer, technologist and technician students, according to race, 1996-2005



Source (DoE 1996-2005)

The enrolment of black technologist students increased from 692 in 1996 to 4667 in 2005, averaging an annual growth rate of 23.62 per cent, and black technicians from 13 897 to 30 328 averaging an annual growth rate of 9.06 per cent (Table 2.4). The proportion of black technologist enrolment compared to white technologist enrolment increased dramatically from 1996 to 2005. In 1996 black technologist enrolments constituted more than a third (37.62 per cent) of all technologist enrolments but in 2005 this proportion increased to more than three quarters (78.99 per cent). The disaggregated black group shows that in 1996 53.86 per cent were African students, while in 2005 this figure increased to 83.60 per cent.

Table 2.4 Average annual growth rate of undergraduate engineering professionals' enrolments, according to race, 1996-2005

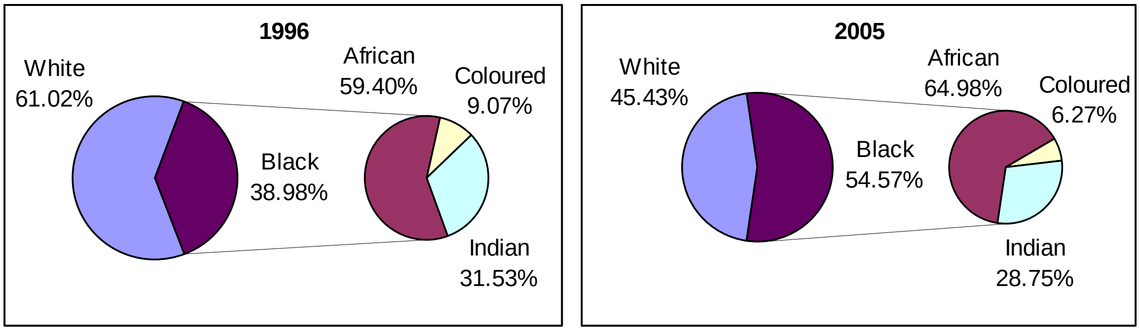
Enrolment	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	% Average annual growth
Black engineer enrolment	3077	3371	3571	2595	3371	3672	3997	4630	5954	6081	7.86
African	1828	2046	2212	1884	2043	2257	2485	2903	3761	3951	8.94
Coloured	279	258	273	225	229	248	271	299	357	381	3.53
Indian	970	1067	1086	486	1099	1168	1241	1428	1836	1748	6.76
White engineer enrolment	4818	4479	4396	3455	3816	3983	4137	4268	4928	5062	0.55
	7895	7850	7967	6049	7187	7655	8134	8897	10883	11143	3.90
Black technologist enrolment	692	1122	1353	1621	4486	8006	8142	5528	3694	4667	23.62
African	373	658	905	1125	3712	7214	7267	4797	3019	3902	29.81
Coloured	159	192	185	177	273	316	375	340	290	342	8.84
Indian	160	273	263	319	502	477	500	391	385	424	11.42
White technologist enrolment	1148	1381	1246	1201	2148	2670	2461	2084	1044	1242	0.88
	1840	2503	2599	2822	6635	10676	10603	7612	4738	5908	13.84
Black technician enrolment	13897	16902	17631	13848	14829	13165	14172	18574	23766	30328	9.06
African	10986	13533	15024	11552	12787	10857	11699	16178	21083	27072	10.54
Coloured	1246	1285	1521	1167	962	1213	1347	1402	1519	1717	3.63
Indian	1665	2084	1086	1129	1080	1095	1126	994	1164	1540	-0.86
White technician enrolment	6529	6286	5334	4077	2429	2057	1984	2352	3257	4536	-3.96
Total black enrolment	17666	21395	22554	18063	22686	24843	26311	28731	33414	41076	9.83
African	13187	16238	18141	14561	18541	20328	21451	23878	27863	34924	11.43
Coloured	1684	1734	1978	1569	1464	1776	1993	2040	2166	2440	4.20
Indian	2795	3424	2435	1933	2681	2740	2867	2813	3385	3712	3.20
Total white enrolment	12494	12146	10976	8732	8393	8709	8583	8704	9230	10840	-1.57
Total engineering enrolment	30160	33541	33531	26796	31079	33552	34893	37435	42643	51915	6.22

Source: DoE 1996-2005

Black technician enrolments comprised more than two thirds (68.04 per cent) of all technician enrolments in 1996 and this figure further increased to 86.99 per cent in 2005, for the reason that the number of white technician graduates decreased considerably. The disaggregated black group shows that the enrolment of Coloured and Indian technician students decreased from 1996 to 2005, while the enrolment of African technician students increased from 79.05 per cent to 89.26 per cent.

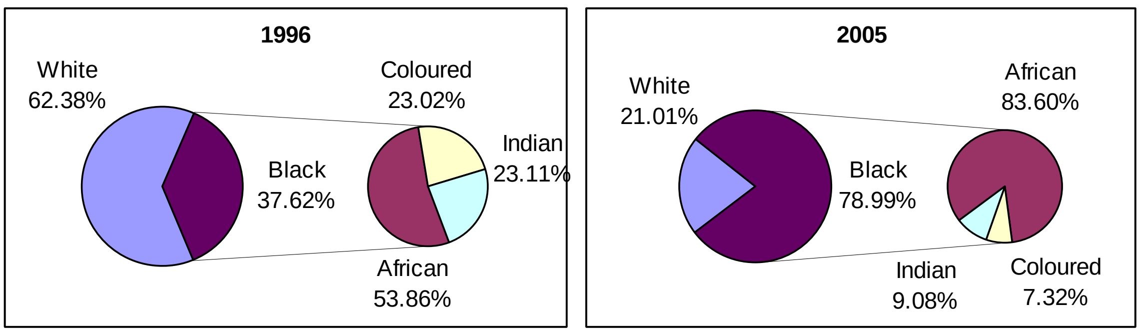
Figure 2.9 Undergraduate enrolment proportions of engineer, technologist and technician students, according to race, 1996 and 2005

Engineer students



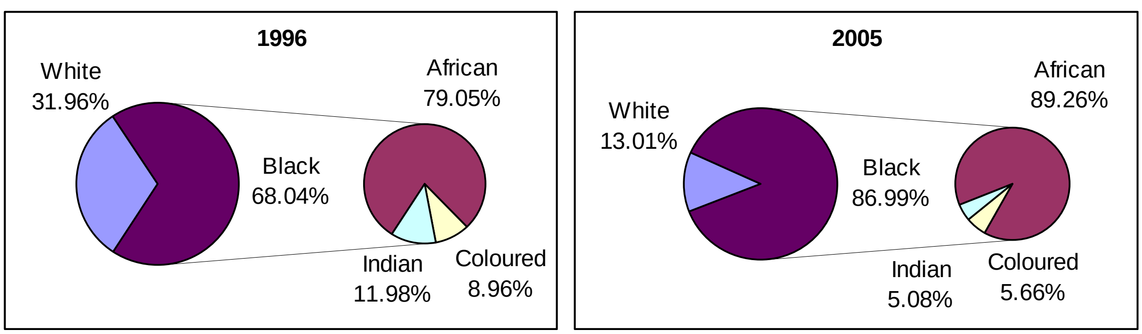
Source: DoE 1996 and 2005

Technologist students



Source: DoE 1996 and 2005

Technician students



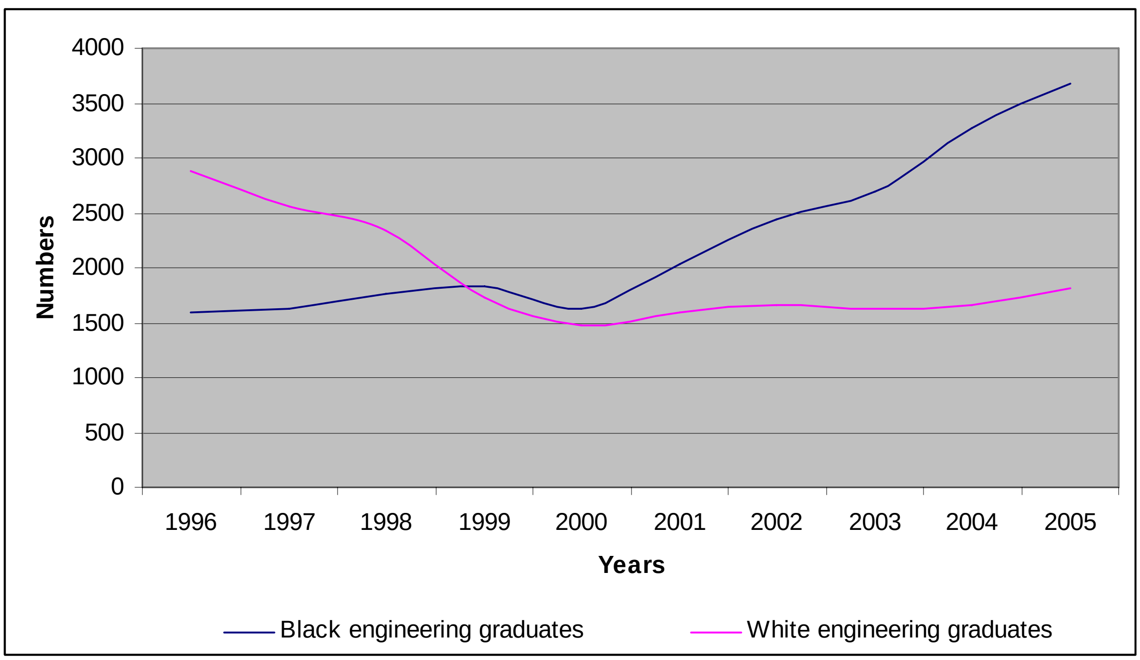
Source: DoE 1996 and 2005

Graduation

Figure 2.10 displays the graduation trends of all engineering qualifications according to race (see Table 2.5). The number of black engineering graduates more than doubled over the 1996 (1 598 graduates) to 2005 (3 685 black graduates) period, indicating an average annual growth of 9.73 per cent over this period. In comparison the number of white engineering decreased with an annual average of 4.99 cent – there were 2 886 white engineering graduates in 1996 and only 1 820 nine years later in 2005.

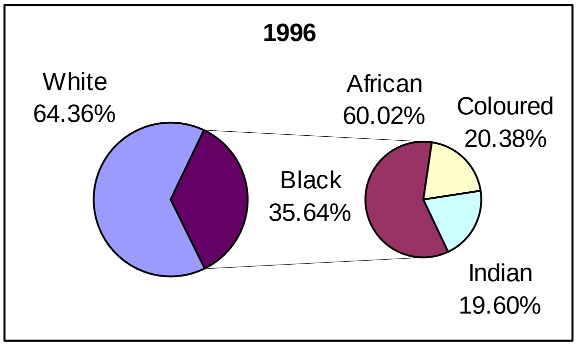
Proportionally, black engineering graduates comprised over a third (35.64 per cent) of all engineer graduates in 1996 compared to more than two thirds (66.94 per cent) in 2005 (see Figure 2.11). Disaggregating the black group shows that the average annual growth rate of graduations for Africans was the highest, 13.51 per cent compared to -1.35 per cent for coloureds and 2.69 per cent for Indians – 959 African engineering students graduated in 1996 compared to 3 000 in 2005.

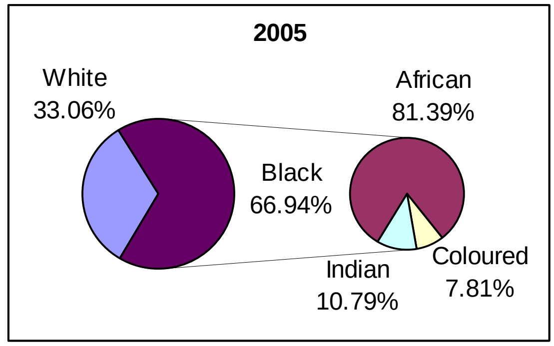
Figure 2.10 Undergraduate engineering student's total graduation, according to race, 1996-2005



Source (DoE 1996-2005)

Figure 2.11 Graduation proportions of all engineering students according to race, 1996 and 2005

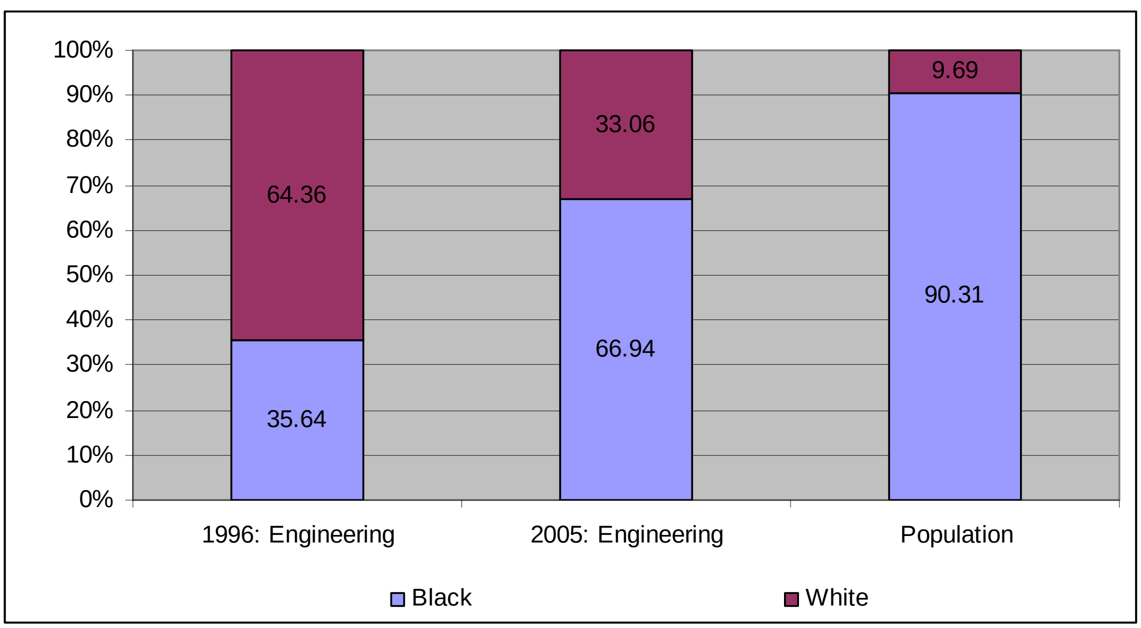




Source: DoE 1996 and 2005

Gradually the proportion of black engineering graduates to the black population is improving and the proportion of white engineering graduates to the white population is decreasing, as shown in Table 2.5. In 1996 black engineering graduates constituted just more than a third (35.64 per cent) and white engineering graduates almost two thirds (64.36 per cent) of engineering graduations (engineers, technologists and technicians), conversely in 2005 black engineering graduates constituted just more than two thirds (66.94 per cent) and white engineering graduates a third (33.06 per cent) of engineering graduations. According to the 2001 Census, 90.31 per cent of the population is black and 9.61 per cent white (Quantec 2007).

Figure 2.12 Proportion of engineering graduations to population according to race, 1996 and 2005



Source: DoE 1996 and 2005; Census 2001

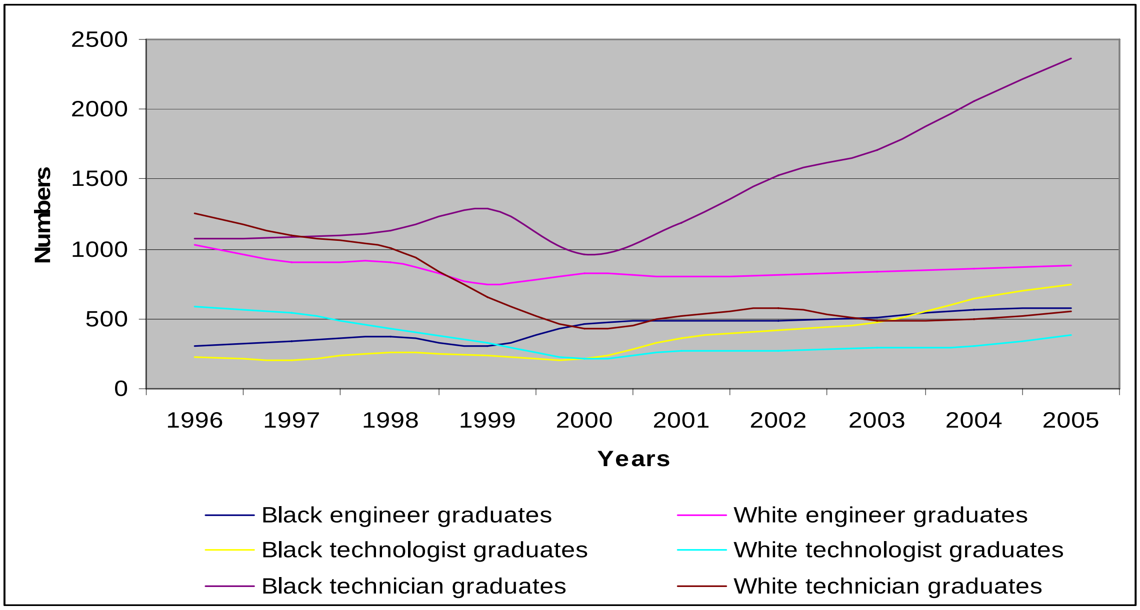
Figure 2.13 (see Table 2.5) shows the graduation trends separately for black engineer, technologist and technician students and Figure 2.14 the graduation proportions in terms of race. The number of black engineer graduates almost doubled from 1996 (306 black graduates) to 2005 (580 black graduates), indicating an average annual growth of 7.34 per cent over this period. Proportional wise black engineer graduates comprised less than a quarter (22.84 per cent) of all engineer graduates in 1996 compared to way more than a third (39.53 per cent) in 2005. The disaggregated black group shows that in 1996 less than half (41.04 per cent) of this group was African, while in 2005 this figure increased to almost two thirds (62.62 per cent) – 126 African engineer students graduated in 1996 compared to 363 in 2005.

The output of black technologist graduates increased from 222 in 1996 to 747 in 2005, averaging an annual growth rate of 14.45 per cent, and black technicians from 1 070 to 2 359 averaging an annual growth rate of 9.18 per cent. The proportion of black technologist graduates compared to white technologist graduates increased dramatically from 1996 to 2005. In 1996 black technologist graduates constituted just over a quarter (27.29 per cent) of technologist graduates but in 2005 this proportion increased to two thirds (66.13 per cent). The disaggregated black technologist group shows that in 1996 just more than half (56.92 per cent) of this group was African, while in 2005 this figure increased to 80.88 per cent – 126 African technologist students graduated in 1996 compared to 604 in 2005.

Black technician graduates comprised almost half (45.91 per cent) of all technician graduates in 1996 and this figure increased to 81.06 per cent in 2005, for the reason that the number of white technician graduates decreased considerably. The disaggregated black technician group shows that in 1996 two thirds (66.10 per cent) of this group was African, while in 2005 this figure increased to 86.17 per cent – 707 African technician students graduated in 1996 compared to 2033 in 2005.

It is noteworthy that there has been an extreme decline in the graduations of coloured and Indian engineering professionals. While the increase in African graduations is encouraging, it had a crowding-out effect on that of Indians and coloureds (Figure 2.11).

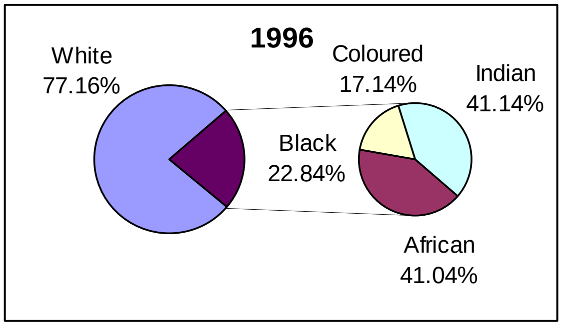
Figure 2.13 Graduations of engineer, technologist and technician students according to race, 1996-2005

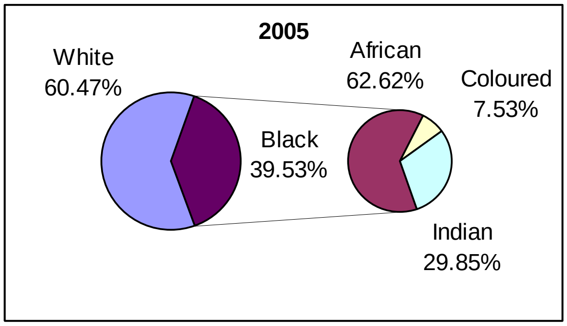


Source (DoE 1996-2005)

Figure 2.14 Graduation proportions of engineer, technologist and technician students according to race, 1996 and 2005

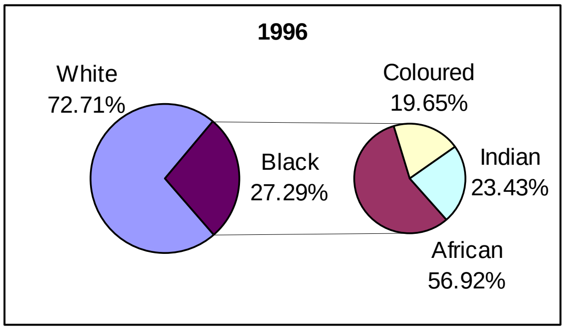
Engineers

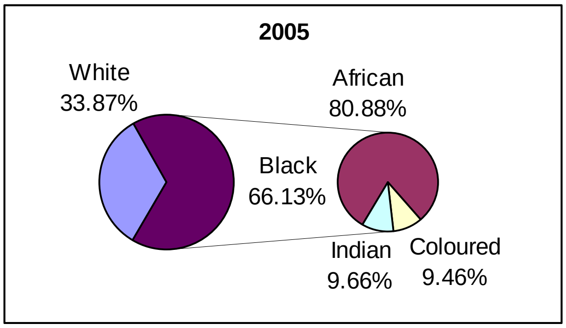




Source: DoE 1996 and 2005

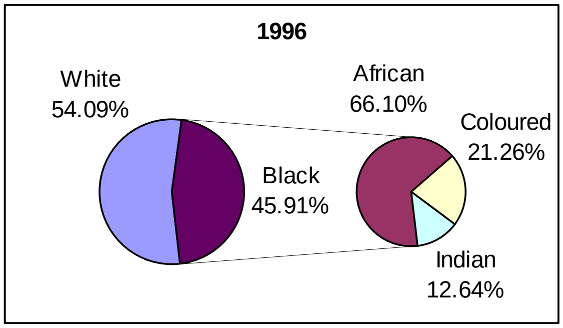
Technologists

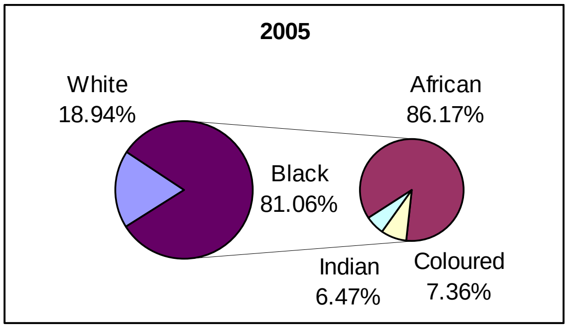




Source: DoE 1996 and 2005

Technicians





Source: DoE 1996 and 2005

Table 2.5 Average annual growth rate of undergraduate engineering professionals, according to race, 1996-2005

Engineering undergraduates	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	% Average annual growth
Black engineer graduates	306	336	369	309	462	484	488	513	567	580	7.34
African	126	151	201	210	252	272	277	307	329	363	12.50
Coloured	55	40	39	37	40	47	46	36	36	44	-2.45
Indian	126	145	129	61	170	165	165	170	202	173	3.59
White engineer graduates	1035	907	908	742	830	803	818	841	858	887	-1.70
Black technologist graduates	222	208	259	235	216	367	420	479	647	747	14.45
African	126	126	157	137	127	262	275	337	498	604	19.01
Coloured	44	39	53	33	37	40	63	59	65	71	5.53
Indian	52	42	49	65	52	65	82	83	85	72	3.72
White technologist graduates	591	548	432	329	217	273	267	294	305	383	-4.71
Black technician graduates	1070	1087	1134	1289	957	1184	1528	1710	2064	2359	9.18
African	707	764	923	1019	754	953	1259	1460	1739	2033	12.45
Coloured	227	135	135	173	110	155	195	201	199	174	-2.95
Indian	135	188	75	97	94	76	74	49	126	153	1.34
White technician graduates	1260	1102	1006	658	428	526	576	486	501	551	-8.78
Total black undergraduates	1598	1631	1761	1832	1634	2035	2436	2702	3277	3685	9.73
African	959	1041	1281	1366	1133	1488	1811	2104	2566	3000	13.51
Coloured	326	214	227	243	186	241	304	297	299	288	-1.35
Indian	313	375	253	224	315	306	321	301	412	398	2.69
Total white undergraduates	2886	2558	2347	1729	1474	1601	1661	1621	1663	1820	-4.99
Total undergraduates	4483	4188	4108	3562	3109	3636	4097	4323	4941	5506	2.31

Source: DoE 1996-2005

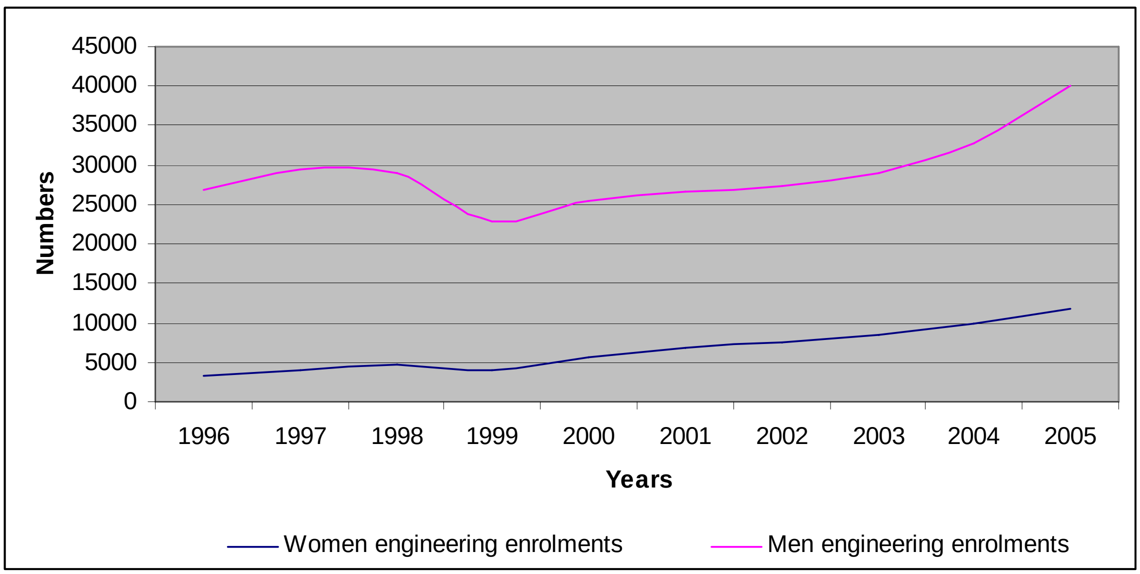
Enrolment according to gender

In terms of gender transformation there has been a related but more limited growth in the participation of women engineering students over the same period. The professional engineering environment can be described as a man's world. Despite many initiatives ranging from dedicated recruitment and selection to the establishment of support groups for women students at training institutions they are still under-represented in the engineering field. Professor Lacquet, the first women dean of the engineering faculty at Wits, holds the opinion that it is not necessary to reach for a goal of 50 per cent women engineering students reminding that not 50 per cent of all nurses are men.[2]

This section only reports on enrolment and graduations trends of women in engineering. Chapter 4 titled 'Women in Engineering' looks at the strategies to enhance women's participation in the engineering field; the factors that influence women in choosing a career in engineering; and the barriers experienced by women in engineering in the labour market.

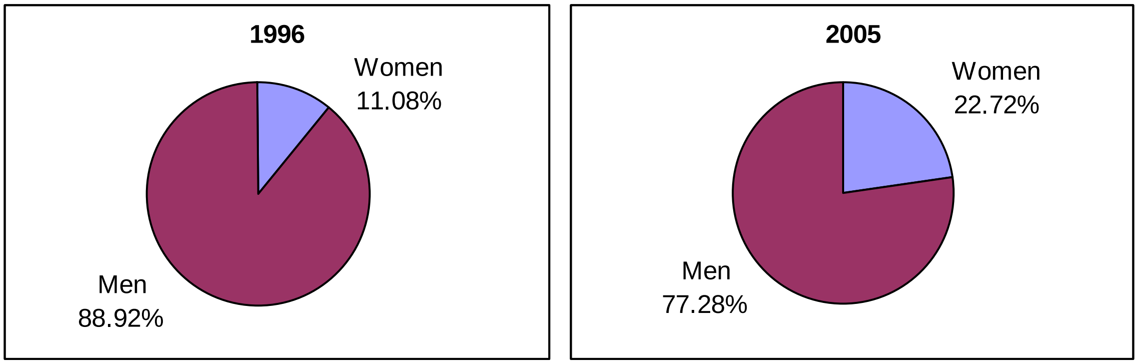
The enrolment of women engineering students more than tripled from 1996 (3 341 women students) to 2005 (11 801 women students), indicating an average annual growth of 15.05 per cent over this period. In comparison the enrolment of men engineering students only increased with an annual average of 4.58 per cent – there were 26 820 men students enrolled in 1996 and 40 142 in 2005. Proportionally, enrolment of women engineering students constituted only 11.08 per cent of total engineering enrolments in 1996, but by 2005 more than a fifth (22.72 per cent) of enrolments in engineering were women.

Figure 2.15 Undergraduate engineering students' enrolment, according to gender, 1996-2005



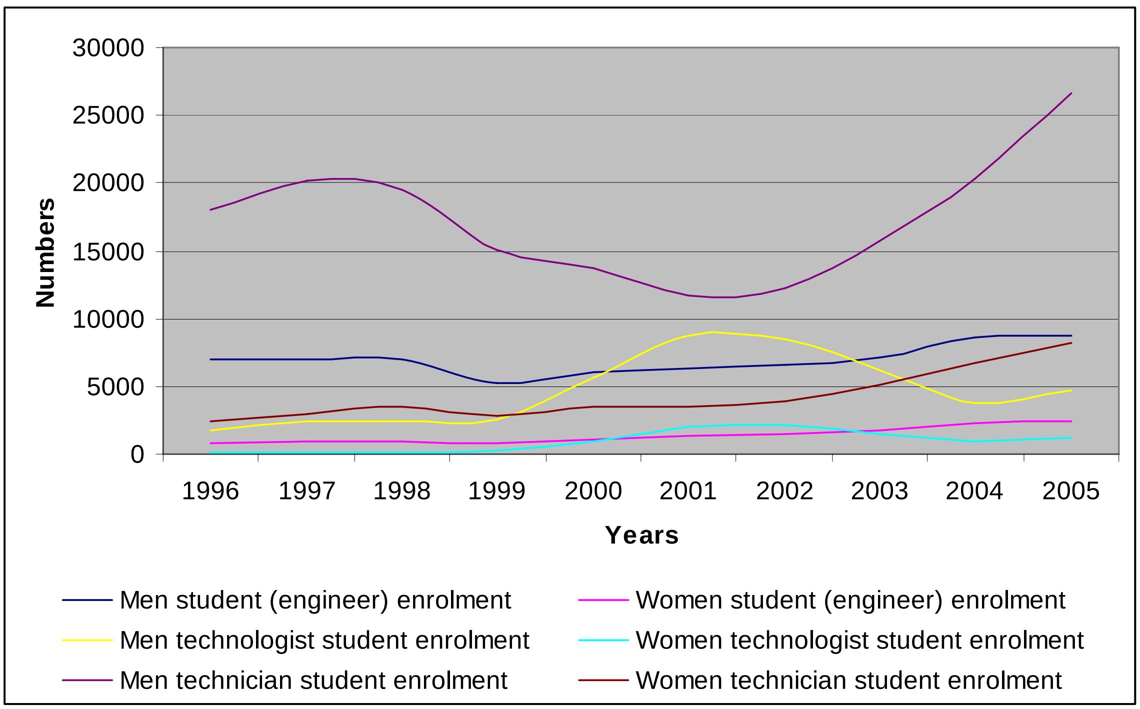
Source (DoE 1996-2005)

Figure 2.16 Undergraduate enrolment proportions of all engineering students according to gender, 1996 and 2005



Source: DoE 1996 and 2005

Figure 2.17 Undergraduate enrolments of engineer, technologist and technician students, according to gender, 1996-2005



Source (DoE 1996-2005)

Table 2.6 Average annual growth rate of undergraduate engineering professional's enrolment, according to gender, 1996-2005

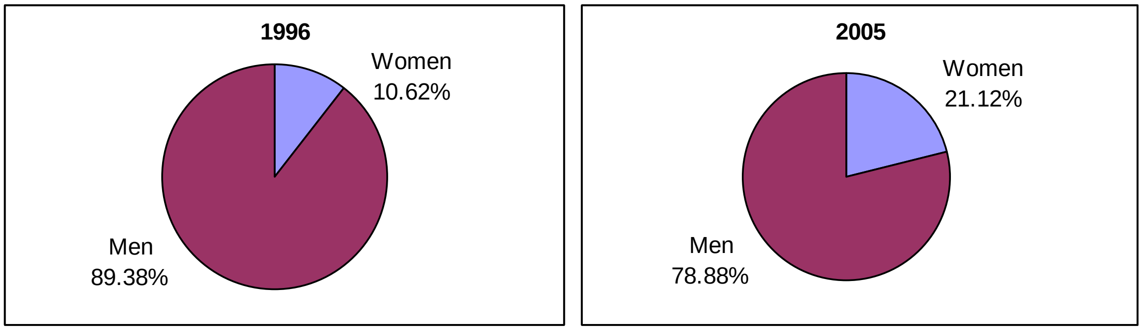
Undergraduate engineering enrolment	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	% Avera annu growt
Men student (engineer) enrolment	7056	6941	6963	5192	6073	6316	6598	7093	8626	8802	2.49
Women student (engineer) enrolment	839	909	1003	857	1114	1339	1537	1808	2259	2357	12.17
Men technologist student enrolment	1728	2359	2454	2567	5631	8717	8502	6172	3785	4730	11.84
Women technologist student enrolment	112	144	145	271	1004	1960	2101	1440	954	1180	29.92
Men technician student enrolment	18035	20165	19446	15133	13719	11676	12208	15750	20258	26610	4.42
Women technician student enrolment	2390	3024	3519	2857	3549	3551	3949	5176	6775	8264	14.78
Total men undergraduate engineering enrolment	26820	29465	28864	22893	25423	26710	27309	29015	32669	40142	4.58
Total women undergraduate engineering enrolment	3341	4076	4666	3985	5667	6850	7586	8424	9988	11801	15.05
Total	30160	33541	33531	26878	31090	33559	34895	37439	42657	51943	6.23

Source: DoE 1996 and 2005

Table 2.6 shows the enrolment trends separately for men and women engineer, technologist and technician students and Figure 2.16 the enrolment proportions. The enrolment of women engineer students almost tripled from 1996 (839 women engineer students) to 2005 (2 357 women engineer students), indicating an average annual growth of 12.17 per cent over this period. In 1996 enrolment of women engineer students constituted just a tenth (10.62 per cent) of all engineer students compared to about a fifth (19.95 per cent) in 2005. The enrolment of women technologist students increased from 112 to 1 180 over the 1996-2005 period, showing an average annual growth rate of 29.92 per cent. Proportionally, women technologist student enrolments comprise less than ten per cent (6.08 per cent) in 1996 compared to almost a fifth (19.97 per cent) in 2005. For women technician enrolments the annual growth rate over the same period averaged 14.78 per cent. In 1996 just more than a tenth (11.70 per cent) of all technician enrolments were women, while in 2005 this figure increased to almost a quarter (23.70 per cent).

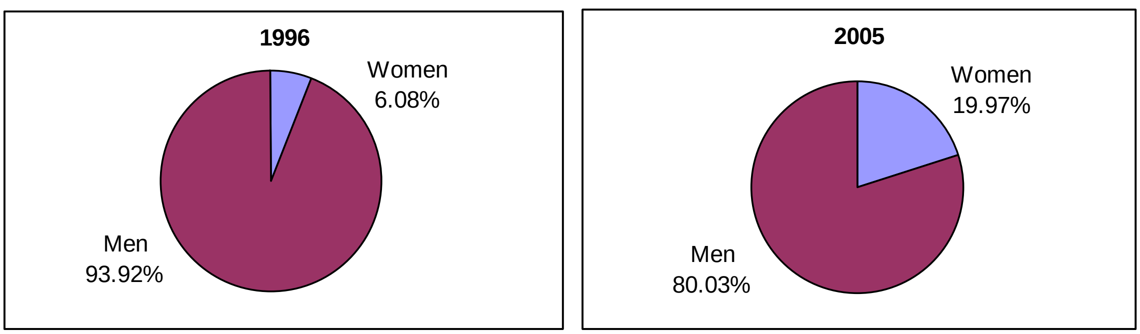
Figure 2.18 Enrolment proportions of engineer, technologist and technician students according to gender, 1996 and 2005

Engineer



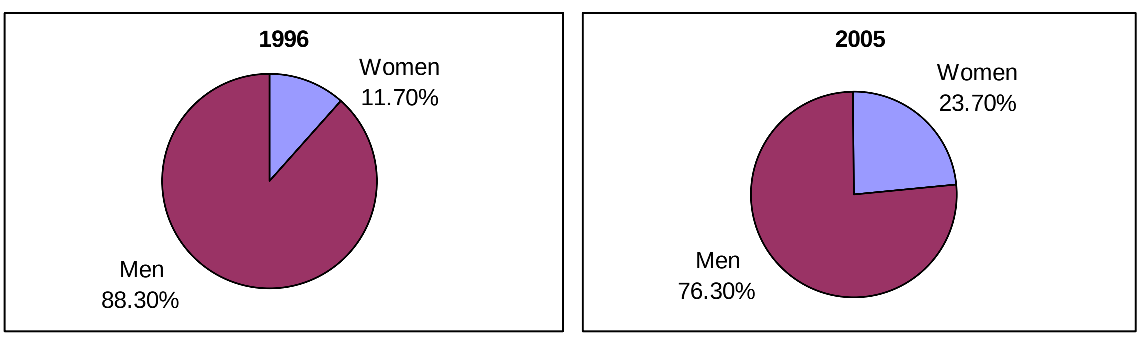
Source: DoE 1996 and 2005

Technologist



Source: DoE 1996 and 2005

Technician

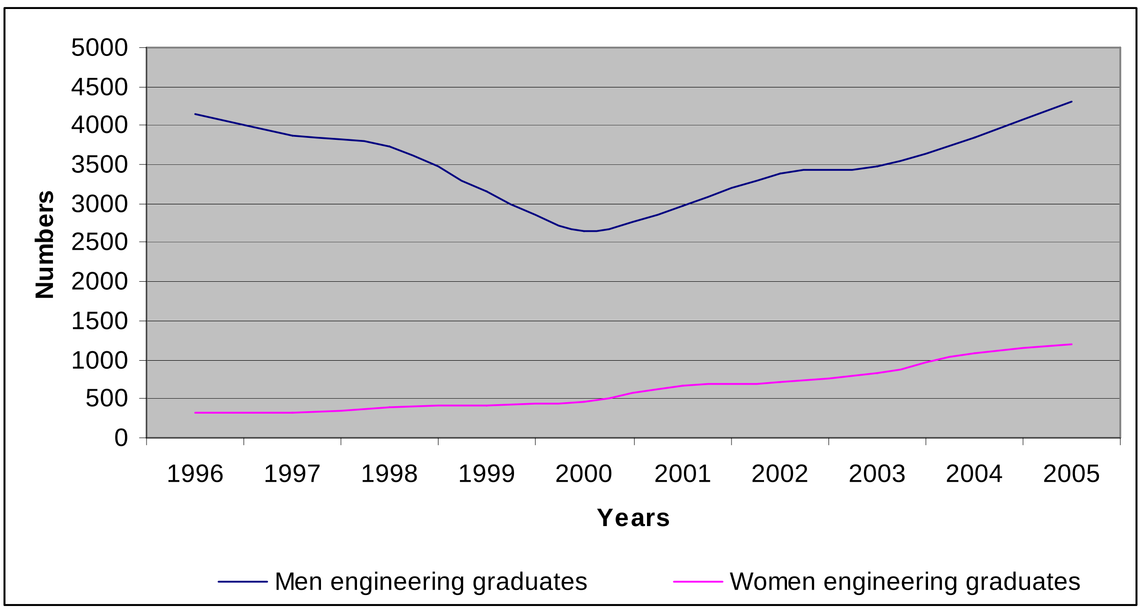


Source: DoE 1996 and 2005

Graduation according to gender

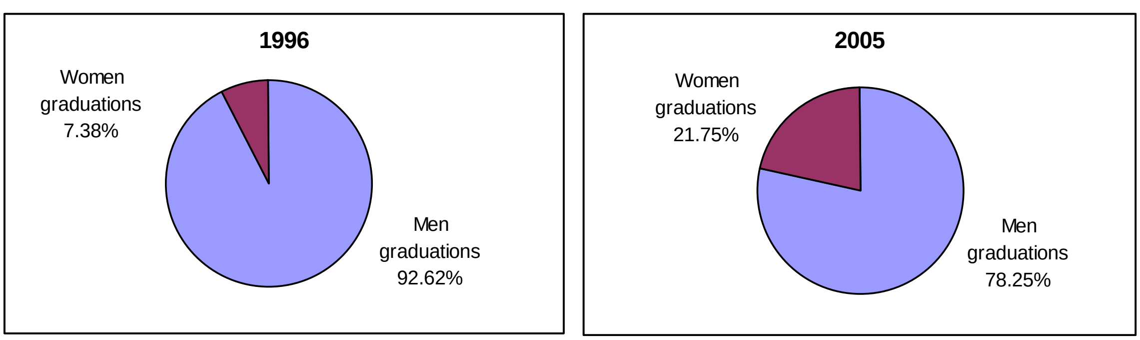
The number of women engineering graduates more than tripled from 1996 (331 women graduates) to 2005 (1 198 women graduates), indicating an average annual growth of 15.37 per cent over this period (see Figure 2.19 and Table 2.7). This may sound like significant growth, but one has to bear in mind that the growth is from a very small base. In comparison the number of male engineering graduates increased with a small average of 0.41 per annum – there were 4 153 men engineering graduates in 1996 and only 155 more (4 308) 9 years later in 2005. Proportionally, women engineering graduates comprised less than a tenth (7.38 per cent) of all engineer graduates in 1996 (see Figure 2.20). In 2005 this figure increased to just more than a fifth (21.75 per cent).

Figure 2.19 Undergraduate engineering student's total graduation, according to gender, 1996-2005



Source (DoE 1996-2005)

Figure 2.20 Graduation proportions of all engineering students according to gender, 1996 and 2005

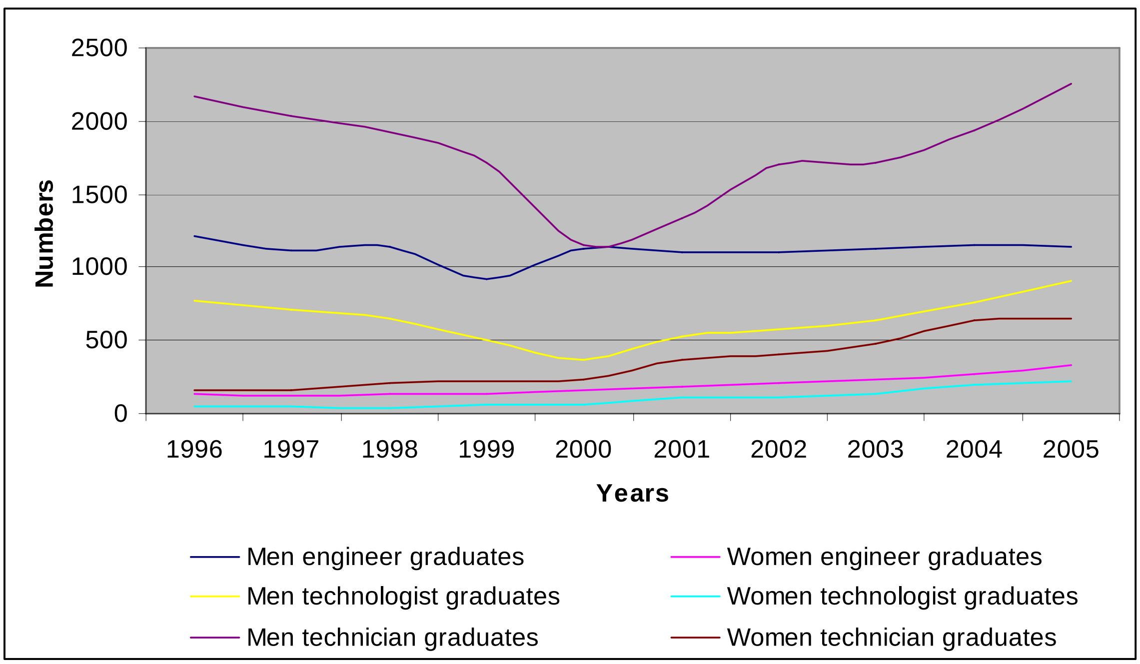


Source: DoE 1996 and 2005

Figure 2.21 (see Table 2.7) shows the graduation trends separately for men and women engineer, technologist and technician students and Figure 2.22 the graduation proportions in terms of gender. In 1996 only 129 women engineers graduated from universities. In 2005 this figure increased to 328, indicating an average annual growth of 10.89 per cent over this period. In 1996 women engineer graduates comprised less than 10 per cent (9.64 per cent) of all engineer graduates. By 2005 this proportion has increased to a fifth (22.34 per cent).

Only 43 women technologist students graduated in 1996 compared to 221 in 2005, indicating an average annual growth rate of 19.89 per cent. The proportion of women technologist and technician graduates compared to male technologist and technician graduates is similar to the proportion of women to men engineer graduates – women constituted less than 10 per cent of graduates in 1996 compared to about a fifth in 2005.

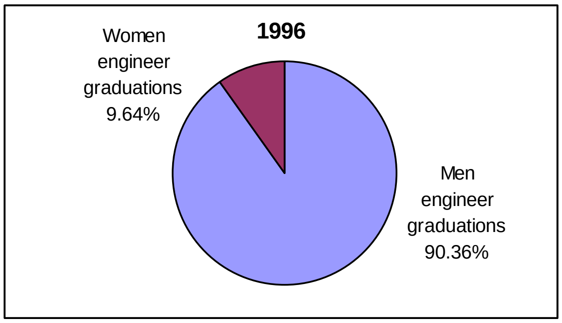
Figure 2.21 Graduation of engineer, technologist and technician students according to gender, 1996-2005

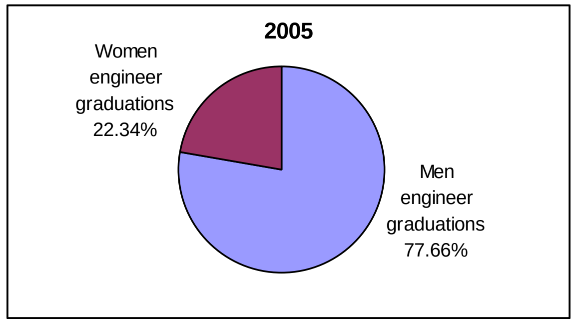


Source (DoE 1996-2005)

Figure 2.22 Graduation proportions of engineer, technologist and technician students according to gender, 1996 and 2005

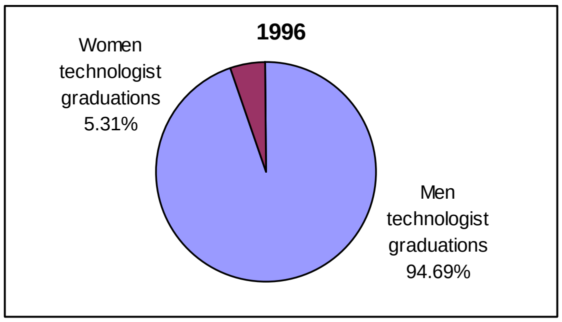
Engineers

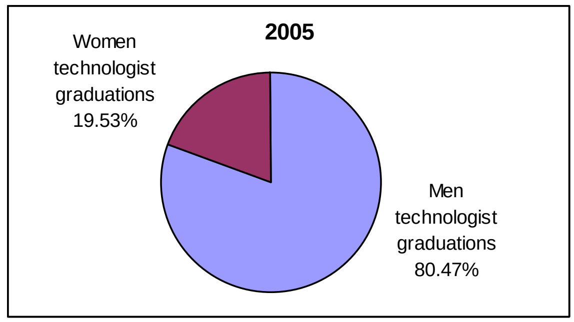




Source: DoE 1996 and 2005

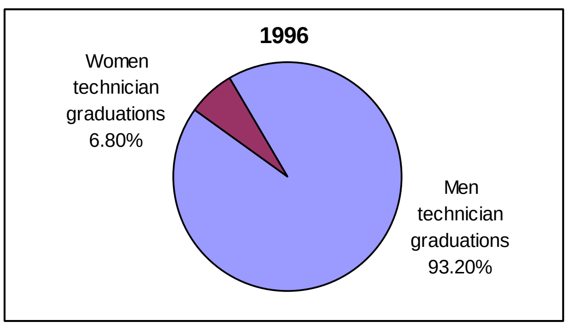
Technologists

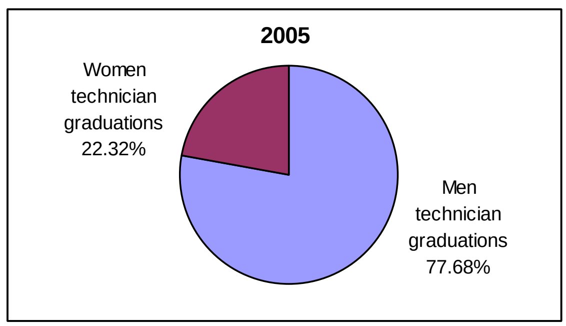




Source: DoE 1996 and 2005

Technicians





Source: DoE 1996 and 2005

Table 2.7 Average annual growth rate of undergraduate engineering professionals' graduation according to gender 1996-2005

Engineering graduations	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	% Average annual growth
Men engineer graduates	1212	1119	1146	920	1130	1098	1103	1128	1156	1139	-0.69
Women engineer graduates	129	124	132	131	162	189	204	227	268	328	10.89
Men technologist graduates	769	712	651	506	372	531	575	643	759	909	1.87
Women technologist graduates	43	44	40	58	60	110	113	129	193	221	19.89
Men technician graduates	2172	2036	1926	1721	1157	1341	1700	1715	1932	2260	0.44
Women technician graduates	159	154	213	226	228	369	404	482	632	650	16.97
Total men engineering graduates	4153	3867	3723	3147	2659	2969	3377	3486	3847	4308	0.41
Total women engineering graduates	331	321	385	415	450	667	720	837	1094	1198	15.37
Total	4483	4188	4108	3562	3109	3636	4097	4323	4941	5506	2.31

Source: DoE 1996-2005

2.5 THE ENGINEERING PROGRAMMES

All engineering programmes at universities and universities of technology are accredited by the Engineering Council of South Africa as per its legislative mandate - the Engineering Profession Act, 2000 (Act 46 of 2000) – and the Higher Education Quality Committee (HEQC) recognises ECSA as an accrediting body for engineering higher education programmes. The accreditation process through ECSA is necessary in order to determine whether the engineering qualifications offered can be recognised by the Council for purposes of registration. Although ECSA's focus is primarily aimed at ensuring that qualifications presented for purposes of registration meet its requirements, the Council also has a wider perspective namely the maintenance of quality in higher engineering education in South Africa as a pivotal driving force towards promotion of the public safety, health and interests, economic viability of the country, and international competitiveness and recognition.

The current education structure comprises an Education Advisory Committee responsible to the Council and the Executive Committee for all aspects relating to education. This Committee is essentially a policy making body which monitors the operational activities of subcommittees acting in terms of defined powers delegated to them. These subcommittees are the following:

- The Engineering Programme Accreditation Committee (EPAC)
- The Technology Programme Accreditation Committee (TPAC)
- The Certificated Engineers Accreditation Committee (CERTAC)

Each of the above Committees has a subcommittee called 'Qualifications and Examinations Committee' (QEC). These Committees are responsible to their principal Committees for the assessment of foreign qualifications and the conducting of examinations and interviews. The three Committees referred to above are directly responsible for the accreditation of engineering programmes at higher education institutions.

The South African Qualifications Authority (SAQA) was established in 1994 and became the legislative body to register standards for educational offerings and certify various bodies - termed Education and Training Quality Assurers (ETQAs) - to perform qualifications assurance. At the same time the National Qualifications Framework (NQF) was developed and established with the aim of enabling progression of learners through all levels and areas of the South African education system.

According to the National Qualifications Framework Bill, 2008, the South African Qualifications Authority Act, 1995 (Act 58 of 1995) is repealed (South African Government 2008). According to the new National Qualifications Framework Act, 2008, a statutory or non-statutory body of expert practitioners in an occupational field must apply to SAQA to be recognised as a professional body in terms of this Act. A professional body must co-operate with the relevant quality councils (QCs) in respect of qualifications and quality assurance in its occupational field, while assuring that public health and safety are still being maintained (South African Government 2008).

The Engineering Standards Generating Body (ESGB) has the function to develop pathways for potential qualifications and standards in engineering; and to generate qualifications and standards in accordance with SAQA requirements for NQF level 4 to 8. These would cover whole and unit standards based qualifications for engineering technicians, technologists and engineers. Furthermore, the ESGB has to recommend qualifications and standards generated; recommend criteria for registration of assessors and moderators or moderating bodies; review qualifications and unit standards; and maintain liason with other SGBs during the process of developing standards and qualifications (Council on Higher Education 2008).

In 1996 the accreditation process had to be adapted because it became necessary to meet ECSA's commitment to accommodate outcomes based learning and appropriate quality assurance methods. The requirements for meeting the Washington Accord mentioned in section 2.1, a system similar to the American ABET, led to the commencement of outcomes-based accreditation in 2001 (Hanrahan 2000). Engineering by the nature of its profession has always been outcomes based in the sense that a person has to be competent. But what has happened since it became formally outcomes based pedagogically is that there is coherence amongst the outcomes and the courses and synergy between courses. According to Jawitz (2001) the new outcomes-based form of accreditation used by ECSA poses a key opportunity for engineering academics to take part in educational issues.

There are two engineering programmes: the engineering degree programme and the technology programme. The engineering degree programme consists of a four year B.Eng. / B.Sc. (Eng.) degree at NQF level 8 (referred to as "professional" Bachelor's Degrees) leading to registration as a professional engineer. This programme is currently offered by the following universities:

- University of Cape Town
- University of KwaZulu-Natal – formed by the merger of the University of Natal and the University of Durban-Westville
- North-West University – formed by the merger of the University of Potchefstroom and the University of North-West, the latter having no B.Eng. / B.Sc. (Eng.) programmes
- University of Pretoria
- University of Johannesburg - former Rand Afrikaans University that merged with the Technikon Witwatersrand, the latter having no B.Eng. / B.Sc. (Eng.) programmes, only N.Dip., B.Tech. and M.Tech. programmes
- University of Stellenbosch
- University of the Witwatersrand

The technology programme consists of a National Diploma (ND in Engineering) leading to registration as a professional engineering technician, and a Bachelor of Technology Degree (BTech) in engineering leading to registration as professional engineering technologist. The technology programme is currently offered by the following institutions:

- Vaal University of Technology
- Tshwane University of Technology - Merger of Northern Gauteng Technikon and Pretoria Technikon
- UNISA – (former Technikon SA that merged with UNISA)
- University of Johannesburg
- Central University of Technology, Free State
- Technikon Mangosuthu
- Durban Institute of Technology – merger of ML Sultan Technikon and Natal Technikon
- Nelson Mandela Metropolitan University – merger of University of PE and PE Technikon
- Cape Peninsula University of Technology – merger of Cape Technikon and Peninsula Technikon
- Walter Sisulu University – merger of Eastern Cape Technikon and Border Technikon

Historically the various engineering programmes have had and continue to have relatively good industry relations. In the university sector relations with industry have often been developed and established through research activities, while in the former technikon sector it has been found that many of the academics have better industry experience than research experience. The nature of these well-established relationships serves as evidence that the outcomes of the programmes correspond with the needs of industry.

In terms of workplace training ECSA identified several Sector Education and Training Authorities such as CHIETA, CETA, ESETA, MERSETA, MQA and TETA who are mandated to facilitate the skills development of engineering professionals. The Council is in the process of developing a close relationship with these SETAs and has so far signed a Memorandum of Understanding with four SETAS. The MoU provides for cooperation in the area of standards generation and quality assurance in the higher education band. Although ECSA's main focus is on the higher education levels of the NQF, it recognises the need for continuity from levels one to four through levels five to eight.

However, despite all these developments there is no change in terms of the organisational system and the delivery of these programmes within an institution. The system still consists of the old departments and faculties at universities and universities of technology.

2.6 CHALLENGES FOR HIGHER EDUCATION INSTITUTIONS OFFERING ENGINEERING PROGRAMMES

2.6.1 Institutional mergers

In 2001 the National Plan for Higher Education proposed institutional mergers. This plan had an arguably greater impact on the former technikon sector than on most traditional universities offering engineering. All except three of the original 11 technikons experienced some form of merger while only three of the seven universities offering engineering were affected. Two universities experienced mergers but retained their traditional university status (the newly formed University of Kwazulu-Natal and North-West University), while one was reformed as a comprehensive university following a merger with a techikon (the newly formed University of Johannesburg). The University of Johannesburg is therefore the only institutional merger that has to deal with both engineering degree programmes as well as technology programmes.

The Dean of the Faculty of Engineering at the University of Johannesburg highlighted the major strengths and weaknesses of the merger for engineering training at this institution (Interview 2006e). According to him this merger brought about transformation in terms of new management, new deans, and a more diverse university population. Although the programmes are still separate because of the outcomes for the BTech and for the B.Eng. degrees and for professional registration requirements, the opportunity now exists more than ever to design articulation pathways.

The complication of the merger lies in the complexity of engineering training at a university and engineering training at a university of technology. This is the first example of the management of these two different paradigms in one leadership. Working with the different cultures poses major challenges because it used to be two different types of organisational processes. This new merger also has to re-strategise their research output – university staff traditionally has a higher research output than the former technikon staff.

2.6.2 Financial constraints

Engineering programmes are costly for the higher education institutions to run, and the subsidy commitment of government has not been sufficient in this regard (ECSA & EASA 1995). This caused some of the smaller departments to form difficult arrangements with external funders (Jansen 2002). Concern was also raised by ECSA about the quality of engineering programmes at some of these smaller departments (ECSA & EASA 1995). One of the major aims of the mergers was to make smaller institutions more effective. However, this process of merging and rationalising programmes seems to be more complicated than anticipated (Interview 2006e). Recently the government made more funds available to some of the higher education institutions through the JIPSA imperative. This is an effort to increase the output of engineering graduates.

2.6.3 Lecturing staff

Tertiary institutions also face challenges relating to the recruitment and retention of lecturing staff, student to staff ratios, research outputs and quality of teaching by staff. There are close to 300 vacancies in engineering departments in the country and there are one lecturer for ever 56 students, where the international standard is one lecturer for every 25 students.[69]

Engineering programmes at tertiary institutions struggle to secure high quality staff to teach in these programmes. This is mainly because industrial engineering salaries are considerably higher than those for engineering academics. Most engineers want a professional job after graduation and do not want to work as academics, making the pool from which to source academics very small. The academic staff turnover is usually high because of the high demand from industry. This breaks the sustainability cycle for training institutions. Even a bigger problem is attracting and keeping candidates who meet equity criteria (Interview 2006e).

Higher education institutions are increasingly focusing on research expertise when considering appointments and promotions. According to d'Almaine et al. (1997) it is also demanded that lecturers at the universities of technology, which historically placed more emphasis on industrial experience, now have to obtain postgraduate qualifications and publish. The objective is that research should influence the quality of teaching positively (Elton 2001).

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69 Universities running on empty *The Star* 9.08.2008

One of the strategies that institutions apply to address the challenges in terms of attracting and retaining staff is to 'grow their own timber'. Institutions take students at an undergraduate level and place them in a developmental programme. The experience shows that such a strategy assists them to successfully complete their master's and doctoral degrees (Interview 2006e) and increases the chance of that person following an academic career. Incentives in kind are also applied to retain staff. This can range from free study fees for children and holidays to one day off a week to do consultancy work. Some of the engineering faculties at higher education institutions have an 'institutional equity policy'. In terms of the implementation it simply means that there is a bias and first priority goes to equity candidates, but they still have to meet the qualification criteria and experience.

The high student to staff ratios at the engineering departments is a big concern (Interview 2006e). The national benchmark is 35 to 1, but a ratio of 100 to 1 is sometimes found especially at universities of technologies. This is exacerbated by the massification imperative of the Department of Education until recently (Interview 2006e). Now the DoE is capping enrolment totals to address issues of quality.

Globally over the past few decades there has been a massive increase in concern over the quality of teaching and learning in higher education programmes across the board (Biggs 1999; Ramsden 2003). Interest in engineering education has been led by organisations such as the American Society for Engineering Education (ASEE) (Wankat & Oreovicz 1993). Domestically, the Centre for Research in Engineering Education (CREE) was established at UCT in 1996 with the goal of promoting engineering education as a feasible research field. According to Case (2006) a national community of concerned engineering educators was established through a series of engineering education conferences since 1997. The magazine 'For Engineering Educators' also saw the light and provides space for the dissemination of good practice and educational research findings both nationally and internationally.

2.6.4 Shift from content-based to outcomes-bases education

Over the recent years there has been a shift in the approach regarding the accreditation of engineering programmes globally. Historically standards were described by the scope of the content and the proportions of theory and practice within a specific training programme. However, international and domestic developments have created an environment in which professional associations are more interested in the outcome of what students have learned rather than the content of a programme – the focus has shifted to the achievement of specific learning outcomes that learners can use when entering employment (Jawitz 1999).

After 1998 the Engineering Council embraced the NQF and adopted an outcomes-based accreditation of whole qualifications. A related influence was the requirement for meeting the Washington Accord, in which outcomes-based education is favoured. ECSA then began outcomes-based accreditation in 2001, operating on an interim license that had been granted by the HEQC. The Council compiled a list of ten general exit-level outcomes, and has been using this in all subsequent accreditation visits.

The shift from content-based to outcomes-based education for the engineering programmes at universities created the following opportunities (Jawitz 2001):

- Engineering departments started discussing the relationship between learning objectives and the learning process and assessment;
- Programmes have the liberty of defining their own content as the focus has shifted from what students know to how students can apply their knowledge;
- Attention is paid to the methodology of assessment; and
- Programmes follow a process of continuous evaluation and improvement.

Universities of technology will only start with outcomes-based education in 2009.

2.7 STUDENT ACCESS AND MOBILITY OR ARTICULATION

Students obtain access to tertiary engineering programmes based on their results in the final matriculation examinations. These results refer to a score representing the overall set of results and a specified minimum symbol in Mathematics and or Physical Science course. Up to now a Higher Grade Mathematics symbol of A, B or C was required to study engineering at university, and for most universities of technology a minimum of C-symbol Standard Grade Mathematics. D symbols are also accepted for extended engineering degree programmes at some universities.

However, in 2008 the new National Senior Certificate examination will be in place and for the purposes of selection to engineering the most dramatic impact will come in the ending of the former Higher Grade and Standard Grade levels at which subjects were offered. According to Case (2006) it seems that the new Mathematics curriculum is pitched roughly equivalent to the former Higher Grade subject, with some additional optional topics. Students who are not taking Mathematics will be required to take a new subject, Mathematics Literacy. The key issue for the tertiary engineering sector will be whether this subject will provide an adequate foundation for certain of its engineering programmes or not. Case (2006) mentions further that Mathematics Literacy is supposed to enable all learners to master some mathematics, but it will not be possible to use it for assessment in a way which will cause candidates to be unsuccessful - the new Senior Certificate will require learners to pass all subjects at the 30% level in order to qualify for a pass. She emphasizes the importance of how it will differentiate at the top end, and whether this would provide sufficient information to identify suitable candidates for engineering courses.

Case (2006) warns that the tertiary sector has not yet stated how it will revise its selection criteria in the light of these new subject arrangements. A further concern is that although some schools are taking precautionary measures by requiring all learners to take Mathematics in case Mathematics Literacy is not accepted for any science or engineering programmes, it is still very unlikely that the pool of students taking Mathematics will be equivalent to the combined previous cohort taking Higher and Standard Grade Mathematics. She expresses her concern about a far reduced pool of potential students if the universities of technology decide not to accept Mathematics Literacy for admission to engineering programmes. According to Case (2006) the new curriculum will not impact that much on programmes that currently require Higher Grade Mathematics for admission.

The provision of funding is another important issue impacting on student access to engineering training at higher education institutions. Traditionally engineering students had access to industrial bursaries or scholarships that involved work agreements with companies after graduation. These working agreements contributed to building a future workforce, and according to Case (2006) companies have recently been able to use these to change the demographics of their engineering professionals. Some of the higher education institutes also offer Financial Aid schemes disadvantaged students who do not have the family means to fund their studies. The introduction in 1999 of the National Student Financial Aid Scheme (NSFAS) enhanced these schemes - the state offers loans and bursaries to qualifying tertiary students. Engineering students who are unable to obtain industrial bursaries can now apply for NSFAS bursaries.

Another problem in terms of access is the ‘revolving door syndrome’ (Case 2006). This refers to students from disadvantaged backgrounds who gain access to tertiary education, but without providing the environment for them in which they can succeed academically. The higher education institutes reacted by establishing academic development programmes to address this problem and Case (2006) reminds us that it was engineering faculties at the former white English medium universities, encouraged by industry, who were leading the establishment of these academic support programmes during the late 1980s.

Some universities currently offer extended degree programmes. Extended degree programmes have replaced the previous bridging courses. Even though the throughput rates of previous bridging courses and extended programmes have often been lower than the conventional engineering programmes, these programmes have clearly had an impact in providing opportunities for students who might not have met the formal entry criteria. These programmes offer extra academic support in the early years to compensate for the schooling backgrounds of disadvantaged students (Jawitz & Scott 1997). There are now significant numbers of engineers in industry who graduated through these programmes.

The widening of access to engineering programmes for women is also an issue. Traditionally only a small proportion of women as described in section 2.4.1 study engineering in general. However, it is found that some engineering disciplines such as chemical engineering attracts bigger numbers of women students. A derivative of the greater number of black students in engineering has been a bigger proportion of women students. The Deputy President of South Africa and leader of the JIPSA initiative recently mentioned the incidence of large numbers of women students with qualifications in the built environment disciplines who had been applying to various infrastructural projects (Case 2006).

Case (2006) points out that one more issue in terms of access is students who wish to study at the undergraduate engineering level on a part-time base. UNISA does provide for part-time diploma and B Technology engineering studies, although B Engineering at universities is offered on a full-time basis. The university sector currently also lack a real mechanism for recognition of prior learning.

Regarding mobility there have been relatively limited opportunities for students to move between the different kinds of engineering programmes offered at the traditional universities and those at universities of technology. This is mostly noticed for students holding a National Diploma or a BTech and who aspire to enter the university B.Sc. (Eng.) programme. Case (2006) indicates that individual departments have sometimes had arrangements in place to grant credit and exemption for particular subjects but this has generally been rather limited and arguably not very successful where it has been implemented. For students who want to articulate from the B.Sc. (Eng.) course to the universities of technology there have generally been systems in place to grant credits for particular subjects across the four semesters of the National Diploma.

The perception was that the National Qualifications Framework (NQF) can make articulation possible between programmes. However, the main function of the NQF is only to publish the exit standards in this regard. It is up to institutions to work out articulation pathways. Case (2006) mentions that there has been strong resistance from the traditional university sector at recognising any equivalence of academic years across the different type of qualifications. She points out that there is specifically a concern about the B.Eng. / B.Sc. (Eng.) degree and BTech being at the same level on the NQF, although both these degrees are four year degrees. According to the Higher Education Qualifications Framework (South African Government 2007: 23) a “professional” Bachelor’s Degree at NQF level 8 has a higher volume of learning and a greater cognitive demand than Bachelor’s degrees existing at NQF level 7. No mentioning of the BTech Degree (also a four year degree) is made on the HE framework.

2.8 ENGINEERING TRAINING BY FURTHER EDUCATION AND TRAINING (FET) COLLEGES

Further Training and Education (FET) colleges in South Africa have historically been offering Trimester N-Stream knowledge-only trade-based programmes. The declaration of Colleges for Advanced Technical Education in 1978 led to the Technikons which divorced themselves from technical colleges. The technical colleges continued offering artisan training programmes at N1-N3 levels and at the same time introduced N4-N6 levels (tertiary) leading to a National Diploma in Engineering.

FET college programmes in engineering have become very limited and narrow in content since they were designed to meet the demands of manual low-skills-low-wages industries (Mbanguta 2003). Due to this the following problems are experienced:

- Universities and universities of technologies cannot recognize the qualifications for articulation purposes.
- The work experiential part cannot be enforced, therefore the uptake of students by employers are very low.
- ECSA demands that the FET college engineering education curriculum be reviewed for recognition as the present qualification confines graduates to operators, repairers and maintenance personnel status – the higher education (N4-N6) levels of these programmes fall outside the binary model of higher education as promulgated in South Africa's Higher Education Act of 1997.

However, the NQF, the FET Act, and the White Paper of 1998 and the Skills Development Act of 1998 gave a new interpretation and definition of a qualification based on an outcomes-based approach. This has implications for the engineering programmes offered at FETs as it is supposed to open up the way for easy articulation to universities of technologies and universities and enhances their applicability to the needs of industry. Some FET colleges already offer the universities of technology National Certificate and National Higher Certificate (NQF Level 5) in engineering. These programmes are accredited and quality assured by the Council on Higher Education/Higher Education Quality Committee (Mbanguta 2003). In 2000 about 74 000 students obtained an engineering qualification at NQF Level 5. This figure was static in 2002 i.e. there was no growth in the output of engineering qualifications at NQF Level 5 at FETs over the 2000 to 2002 period.

2.9 ENGINEERING TRAINING THROUGH LEARNERSHIPS

Skills development in South Africa is intended to improve productivity, employment creation and competitiveness. Accredited work integrated learning programmes, learnerships, are at the heart of the Department of Labour's skills development strategy. They are aimed at providing workplace learning in a structured form, linked to multiple sites of work experience, and culminating in a nationally recognized qualification. Learnerships were proposed to be particularly significant in occupations in economic sectors experiencing skills shortages, or those identified as critical priorities for economic growth.

Learnerships are seen as different to apprenticeships in that success is measured by the ability of the learner to use the skills taught in the workplace.

Central to a learnership is a combination of theory and practice, and assessment towards accredited qualifications is focused on performance of key tasks.

Only 629 learners registered for engineering related learnerships since 2000 through the CETA, CHIETA, ESETA and MERSETA. Most of these (510) were at NQF Level 6 and 117 were at NQF Level 5. Only one learner registered at NQF Level 7 (Master's degree level) and also one learner registered at NQF level 8 (Doctorate level). The learnerships fields were:

- Civil Engineering
- Analytical Chemistry
- Chemical Engineering
- Electrical Engineering
- Mechanical Engineering
- Polymer Technology
- Electronic and Computing Systems
- Programming
- Fossil Power Plant Process Control
- Nuclear Power Plant Process Control
- Systems Support Engineer

There are requests for the conversion of the national diploma in engineering to a learnership (Lawless 2005) to address the lack of experiential training opportunities - some of the universities of technology are trying to use a learnership route to support access to experiential learning. The relevant SETA registers the learnership, the university of technology offers the learning component (which is the existing programme), and the SETA locates an employer where the student can do his workplace training component. In this way the student can obtain a qualification and the employer is compensated for its training endeavour.

2.10 CONCLUSION

The secondary school education system in South Africa is inadequate in terms of its capacity to develop and supply a suitable pool of candidates for engineering studies at higher education institutions. Before a sufficient pool of learners with Mathematics and Physical Science qualifications can be supplied in future for training in engineering at universities and universities of technologies, the schooling system should do the following: identify learners with the potential to pursue Mathematics and Physical Science; ensure that there are enough well-qualified Mathematics and Physical Science teachers available to improve tuition in these subjects; create an awareness of the engineering study field for potential students through career guidance; guide the Mathematics and Physical Science learners through the secondary school phase;

and assist them to gain entry to tertiary education in engineering at a higher education institution.

South Africa needs a significant number of engineering graduates to ensure sustainable growth. Although there was an increase in those studying towards an engineering qualification at the universities and universities of technology, the throughput rates to deliver engineering graduates are still poor - there has only been a marginal increase in the absolute number of engineering graduates the past ten years. For higher education institutions to provide enough engineering graduates to industry the following is needed: the entrance criteria must be re-visited in order to ensure better throughput rates; the scope and quality of courses must be aligned with industry needs; the number and quality of lecturers must be improved; resources at tartiary institutions need to be addressed; experiential training opportunities must be arranged; and graduates must be assisted through placement agencies to access employment opportunities.

CHAPTER 3

WOMEN IN ENGINEERING

In 1945 there were no women in engineering in South Africa but by 1974 more and more women gradually became part of the engineering profession (Interview 2006a; Interview 2006f; Interview 2007c). In 1996 about 16.21 per cent of engineering professionals who participated in the South African Labour Market were women. In 2005 this figure decreased to only 10.51 per cent (Quantec 2007). The declining trend is not only alarming in the context of the critical shortage of engineering skills in South Africa, but also highlights the continued under-representation of women in engineering.

3.1 STRATEGIES TO ENHANCE WOMEN TAKING PART IN ENGINEERING

The professional engineering environment can be described as a man's world. Phipps (2002) emphasized that the perception of engineering as being a man's job male-identified is a major factor contributing to the female minority. Traditionally it is also experienced that women are not attracted by technology. Despite many initiatives ranging from dedicated recruitment and selection to the establishment of support groups for women students at training institutions and women workers in the labour market, they are still under-represented in the engineering field.

Although South Africa is the top performer in the Sub-Saharan African region (Hausman Tyson & Zahidi 2006) and does well on political empowerment, as more than 40 per cent of its ministers are women and more than a third of the positions in parliament are held by women, the country scores poorly on gender economic participation and opportunity and has closed only 56 per cent of its economic gender gap (placing it at 79th position among 115 countries).

The percentage of women undertaking engineering courses in South Africa has increased from 9.4 per cent in 1996 (DoE) to 20.2 per cent in 2005 (DoE). This shows that initiatives to attract Grade 12 girl learners to entering engineering studies are making progress. However, although women constitute about a fifth of the engineering student population since 1996, they represent only about 10 per cent of the engineering workforce (Quantec 2007). It seems that the emphasis should not only be on recruitment, but also on retention (Roberts & Ayre 2002).

The Employment Equity Act, 1998 (Act No. 55 of 1998) is a good example of an active labour market policy to increase women's participation in the labour market (SA Government 1998). The Act prescribes the representation of blacks, women and disabled employees in organizations according to the population distribution in South Africa.

The National Research and Development (R&D) Strategy (2002) recognises that human resource (HR) development in science and technology is not being adequately developed and renewed. The strategy proposes a highly targeted approach towards increasing excellence in mathematics and the sciences among black matriculants and young women. New Centres of Excellence are being established to attract young people to sustainable careers in scientific research. Special programmes for the promotion of women in science and engineering have also been proposed.

Two of the positive outcomes of the R&D strategy have been: the establishment of the SET4Women Reference Group (SET4WRG) as part of the National Advisory Council on Innovation (NACI). The SET4WRG consists of women stakeholders and representatives of organisations with an interest in the progress of women in science and engineering. It serves to monitor and advise the Department of Science and Technology on relevant issues; and the National Research Foundation which was tasked to set up an R&D capacity-building programme for Historically Disadvantaged Individuals.

A Gender and Race Equity policy is at present under development for the Department of Science and Technology through the SET4Women Reference Group (SET4WRG). The intention is that the policy framework will guide institutions forming part of the National System of Innovation (NSI). The policy framework addresses science, engineering and technology (SET) for women.

The EU Commission Report (2006) states that it is known that women engineers bring diversity to the mono-cultural engineering workforce and therefore extend the impact engineering has on society. Women usually show interest in the social aspects of technology and science and can make a significant contribution to social and environmental questions.

The career path of a women engineer already starts at an early age and includes key junctures such as choosing school subjects, enrolling at a training institution, entering the labour market and progressing in the labour market. In the context of the shortage of engineering skills in general and more specifically women engineering skills, it is important to understand the internal and external influences that affect women’s choices of engineering and the barriers that exist that prevent women engineers from full participation and success

3.2 FACTORS INFLUENCING WOMEN IN CHOOSING ENGINEERING AS A CAREER

There are a number of influences that seem to affect the choice of engineering as a career option for women. These influences are *inter alia* an early interest in science subjects at school level, the quality of education received in science subjects at school level, social influences such as the role of parents or role models, and the availability of information (EU Commission Report 2006; Phipps 2002). The desire to contribute to society is a strong factor for women in choosing engineering (Isaacs 2001). Jawitz and Case (1998) found in a study in South Africa that black women engineering students were attracted to an engineering career based on their perceived roles in the community. This shows that women prefer engineering to be linked to a social context. The choice of following an engineering career already starts in Grade 9 when a learner has to choose school subjects. An early interest in scientific subjects appears to be a decisive factor for choosing an engineering career later. In South Africa, especially for black female learners, there are still stereotypes around gender and the ability of women to perform in subjects such as Mathematics and Physical Science. Black female learners at school are therefore kept from pursuing a career in engineering. Jawitz, Case and Tshabalala (2000) found that a positive attitude towards science at school can lead to choosing engineering as a career. The quality of Mathematics and Physical science education in South Africa is a further problem. The opportunity for learners to choose science subjects in order to pursue studies in engineering is affected by poor education in these subjects at school level.

Engineering is not always the exclusive choice of an individual and in many instances it is found that their families have influenced them. The EU Commission Report (2006) conveys that the level of education of the two parents of women engineers has an important influence on their choice of engineering as a study field and career; even more so if they have engineers in their family or close environment. A number of other studies also emphasise the positive effect of a role model on choosing engineering (Carter & Kirkup 1990; Coles 1994; Smith & Erb 1986).

The EU Commission Report (2006) found that the lack of information was one of the major factors influencing women to consider a career in engineering. As stated earlier, none of the students interviewed in their *Womeng Project* had any precise information about the job and the actual activities of an engineer. This means that none of them had a good idea of their future career paths as engineers when they started their training. Usually training institutions that offer engineering studies have information policies and events to inform potential students about the course. The Report mentions that getting information through personal contact seems to be a decisive factor. They found in their study that the most effective opportunities for personal contact are Open Days at training institutions.

3.3 BARRIERS EXPERIENCED BY WOMEN IN ENGINEERING IN THE LABOUR MARKET

There is no convincing evidence that women's representation in science and engineering is limited by innate ability (Handelsman 2005). Research now tends to focus more on how the work environment and scientific culture itself acts as a barrier to women rather than the notion that women themselves lack the requisite skills (Bebbington 2002).

The engineering working environment is male dominated and the working conditions do not always accommodate women workers. There are a number of studies identifying the barriers that exist and that hinder women engineers from fully participating and progressing in the labour market (Evetts 1994; EU Commission Report 2006; Isaacs 2001; Rosser 2004; Taniguchi 1999).

Some of the most significant barriers identified are balancing work with family, gaining credibility and respectability amongst male peers, dual careers, lack of mentors due to small numbers of women engineers, access to networks, and inequality in terms of salaries and promotion opportunities.

Balancing work with family seems to be the most significant challenge women engineers face (Goldberg 1998; Interview 2007d; Rosser 2004; Sonnert 1999, Maskell-Pretz & Hopkins 1997). Some of the strategies women engineers apply to achieve a balance are having children later in their careers, negotiating part-time and flexible working hours or even career breaks (Evetts 1994; Interview 2006i). Women engineers reported that it is not always easy to negotiate part-time contracts in some sectors (Interview 2007c).

Dual careers seem to be a huge problem for some women engineers (Interview 2006i, Interview 2007c). It is often found that women engineers are married to professional men. The attitude of the husband or partner is a key factor in the dual career dilemma. Cultures may differ but it is traditionally expected of women to take care of children. Women engineers reported that they are usually the ones who have to make sacrifices in their careers if they are married to a professional man. If the husband's career prospects are considered more promising than the wife's, preference is often given to the husband's career development (Sonnert 1999). Younger generations seem to handle dual careers better (EU Commission Report 2006).

Regarding discrimination, women engineers face a number of obstacles in the workplace. These usually relate to issues such as getting recognition for the work they do, access to networks, remuneration and promotion opportunities (Conrad, 2001; Interview 2006i). It seems that the "old boys" networks are much more effective than the women's networks (Goldberg 1998; Phipps 2002). The small number of women engineers does not allow the same network opportunities.

It is clear that it is not women's insufficiencies that prevent them from entering the engineering field, but rather social and institutional structures and barriers. Some of the women engineers who were interviewed feel very strongly about the fact that women should know and accept the realities of the engineer's workplace, accept that it is traditionally seen as a man's world, adapt and "…just get over it" as one commented (Interview 2007d). Some of those interviewed indicated that there has definitely been a change in the corporate working environment to accommodate women more, but that working realities, especially on sites in the construction industry, still pose challenges for women engineers (Interview 2006i; Interview 2006j).

3.4 GRADUATIONS OF WOMEN IN ENGINEERING

There has been an improvement in the number of women graduates in engineering at universities from 1996 to 2005, as shown in Table 3.1. South African policies and labour laws are in place to address equity and transformation – aspiring women engineers are awarded bursaries (Interview 2006k; Interview 2007c), the universities have supplementary courses in place and cultural diversity issues are being addressed (Interview 2006g; Interview 2006h). Black women engineering graduates had the strongest growth (27.88 per cent), followed by a 9.43 per cent growth in the number of black men engineering graduates, 6.05 per cent in the number of white women engineering graduates and a negative growth in the number of white men engineering graduates. Even though there was a total growth of 12.13 per cent in women graduates, it occurred from a small base. In 2005 men still constitute the majority of engineering graduates at universities.

Table 3.1 Graduation growth at universities (engineers) according to race and gender, 1996 and 2005

	1996	**2005**	**Average annual growth**
	N	N	%
Black Women	27	247	27.88
Black Men	337	753	9.34
White Women	155	263	6.05
White Men	1352	1208	-1.24
Total	1871	2470	3.13

Source: DoE (1996 & 2005)

Also at universities of technology, from which technologists and technicians graduate, there has been an average annual growth of 24.12 per cent from 1996 to 2005 in the number of black women technologists and technicians (see Table 3.2). Black male technologist and technician graduates also show an increase of 7.82 per cent over the nine-year period. However, white women technologists and technicians declined with an average annual growth rate of –3.31 per cent and white men technologists and technicians with an average annual growth rate of –7.46 per cent from 1996 to 2005. Similar to the picture at universities in 2005 men still constitute the majority of graduates in engineering at universities of technology compared to women.

Table 3.2 Graduation growths at universities of technologies (technologists and technicians according to race and gender, 1996 and 2005)

	1996	2005	Average annual growth
	N	N	%
Black Women	116	811	24.12
Black Men	1180	2324	7.82
White Women	88	65	-3.31
White Men	1804	898	-7.46
Total	3187	4098	2.83

Source: DoE (1996 & 2005)

Enrolment and graduations of women engineering students are still lower than enrolment and graduations of male engineering students, but the throughput of women engineering students is slightly higher than the throughput of male engineering students. This has been confirmed in interviews at universities (Interview 2006g; Interview 2006h). Women university students tend to be more mature, have better life skills, are more focused and at some of the universities women were the top students for up to six consecutive years (Interview 2006i; Interview 2006g).

Conversely, the throughput of women technologists and technicians has decreased and the throughput of male technologists and technicians has increased at universities of technology. In 1999, a third of the women students who enrolled in 1996 at universities of technology graduated, but in 2005, only 14.4 per cent of the women students who enrolled in 2002 graduated. Only 5.8 per cent of the male students who enrolled at universities of technology in 1996 graduated in 1999, while 15.3 per cent of the male students who enrolled in 2002 graduated in 2005.

The drop-out rate of engineering students has many contributory factors. Major campaigns were mounted in the early 1990s to encourage historically disadvantaged learners and women to enter engineering studies without providing enough information, and without selection and pre-testing to determine their suitability for the engineering work environment and their emotional intelligence (Interview 2006g; Interview 2006j). The incentive or motivation to study for a specific qualification must be intrinsic and not external through a bursary (Interview 2006g). Some historically disadvantaged students have a poor foundation in mathematics (admitted with only a D symbol) and do not have a command of the language of instruction (Interview 2006h). Special courses at universities are offered to improve language proficiency. Previously institutions were not geared to offer supplementary courses, although this has improved and many universities currently offer bridging courses and psychological support to historically disadvantaged entrants to cope with tertiary education (Interview 2006h; Interview 2006g). About half of the students who enrol for extended programmes eventually graduate (Interview 2006g). Previously institutions also did not attend to cultural diversity issues either, but this is changing and tertiary institutions are incorporating modules that address gender and cultural sensitivity (Interview, 2006d). However, staff in most engineering departments is white men and there are still not enough women role models in engineering departments at tertiary institutions. Women staff at universities tends to reach a glass ceiling (Interview 2006i).

3.5 EMPLOYMENT OF WOMEN IN ENGINEERING

Section 1.3.5 discussed the employment of women and men engineers, technologist and technicians in the labour market from 1997 to 2005. On average about 12 per cent women worked as engineers and technologists in the 1996-1999 period, but this figure dropped to under 10 per cent (8.48 per cent) in the 2000-2005 period, despite the fact that the supply of women graduates has increased with an annual average of 15.30 per cent between 1996 and 2005 (DoE 1996 & DoE 2005). It is noteworthy to mention that the decrease in the employment of white women engineers and technologists over this period is primarily responsible for this negative trend. The same downward trend is noticed for women engineering technicians. This is indicative of the continued under-representation of women in engineering in the South African labour market.

Differences in remuneration for women and men working at the same levels can be seen as an indication of discrimination in the labour market. Although there is still under-representation of women in engineering in the South African labour market, remuneration figures show that salaries of women in engineering in South Africa have improved with an average annual growth of 16.12 per cent between 2000 and 2005. However, in 2005 women engineering professionals still earned 17.8 per cent less than their men counterparts.

There was a negative growth in the remuneration of managers in engineering over this period, but what is very encouraging is that the remuneration of women managers in engineering has slightly surpassed that of male managers over this period. It was confirmed during interviews that the remuneration of women in engineering has indeed increased, especially remuneration of black women in an attempt to comply with equity requirements (Interview 2006j; Interview 2007c).

3.6 CONCLUSION

The capacity problem in engineering is a worldwide phenomenon. The under-representation of women specifically in engineering is explained by the factors that influence them to choose an engineering career as well as the barriers that prevent them from fully participating in the labour market.

From 1996 the data show that there has been an increase in women engineering graduates but a decrease in women in engineering (engineers, technologists and technicians) employed in the labour market. One of the reasons for this trend may be the issue of balancing work and family life. Most literature, as well as the interviews conducted by the researchers revealed that this is one of the major barriers that prevent women engineers from full participation and progress in the labour market.

Although employment of women engineers and technicians combined has decreased, it looks as if efforts to entice more women (especially black women) into engineering studies have not been in vain, as both enrolments and graduations are on the increase. Enrolment and graduations of women engineering students is still lower than those of men, but the throughput of women engineering students is slightly better than the throughput of male engineering students.

Various academic development programmes are opening up the professions and increasing access in line with employment equity requirements. It appears that these efforts have been quite successful in addressing the quality of school-leavers who make up the intake at tertiary institutions, as throughput is increasing gradually. The poor quality of mathematics and science education at school level, coupled with the need for improving the school system, is, however, still a problem that should be one of South Africa's highest national priorities.

The supply of women engineering graduates has increased significantly, but it seems that many women graduates do not follow an engineering career after graduation. This may be due to various reasons. It has been found that intrinsic motivation as opposed to external motivation (such as bursaries) is more important in choosing a career. Firstly, the selection of women engineering students with appropriate personalities is important; all information with regard to the working environment needs to be communicated to allow aspiring engineering students to make the correct choice.

Some of the most significant barriers identified are balancing work with family life, gaining credibility and respect from men colleagues, dual careers, lack of mentors, access to networks and inequalities in remuneration and promotion opportunities. Some strategies that women apply to achieve a balance are having children later in careers, negotiating part-time and flexible working hours or even career breaks. Not all sectors, however, are prepared to negotiate part-time contracts.

South African policies and labour laws are in place to address equity and transformation, aspiring women engineers are awarded bursaries, the universities have supplementary courses in place and cultural diversity issues are being addressed. The working environment in South Africa has changed over the last 10 years, but some sectors still need to change to accommodate women. However, women themselves need to gain knowledge about the engineering working environment, and adapt and plan their careers accordingly.

CHAPTER 4

CONCLUSIONS

The capacity problem in engineering is a world wide phenomenon, but issues such as migration, equity, lack of experiential training opportunities, shortage of mentors, and the expansion of infrastructure spending further complicate the South African situation.

There is positive growth in engineering employment, especially in the number of technicians which bodes well for reaching the ideal ratio of one engineer/technologist to four technicians. However, most engineering professionals worked in the financial and business services sectors where they do not always apply their technical skills, but assist with risk management in the industry through consulting agencies. Incentives are necessary to attract these qualified engineering professionals back into the engineering environment.

The construction industry grew the last couple of years in response to infrastructure expansion. This led to a demand in employment especially in the public sector, but it will take time to overcome current skills shortages. Furthermore, economic growth based on growth in the construction sector is an unsustainable strategy, as construction work is cyclical.

Progress in racial transformation is visible in graduation, as well as employment figures. Engineering graduations in 2005 were two-thirds black and one third white. Although encouraging, it is noteworthy that there has been a major decline in the graduations of coloured and Indian engineering professionals in proportion to African graduations.

Although progress has been made with regard to transformation in the labour market, a shortage of black engineering professionals will continue to be a problem for many years, as it takes time to gain work experience and it will therefore be more appropriate to set current equity targets based on the demographic profile of available engineers (44.07 per cent black and 55.93 per cent white) and future equity targets on engineering graduations (a two-thirds black and one third white), as well as the number of suitable matriculants than on the country's demographics (90.31 per cent black and 9.69 per cent white). Experienced engineering professionals are required to train and develop future engineering professionals – one cannot put old heads on young shoulders, as maturity improves over time. A major shortage of older and experienced professionals is noticed which impacts on the transfer of skills to the younger generation of engineering professionals.

The employment of women in engineering shows a decrease during the 1996-2005 period and the under-representation of women in the engineering labour market remains an issue. Our research found that women and men each contribute to engineering in a unique way and women engineering students often outperform their male counterparts. Women are valuable in engineering, as they bring a different angle in addressing challenges than men do and men and women thus complement each other in the engineering environment. However, although more women engineering professionals are currently being supplied by tertiary institutions than previously, there are still an insufficient number of experienced women engineers to assist with training and development. There just are not enough women engineering professionals to address employment targets. According to Prof Beatrys Lacquet (first women dean of the engineering faculty at Wits), it is also not necessary that half of all engineers should be women, as not half of all nurses are men.[2] Many women engineering graduates go into business and finance, as engineers have broad based skills. It is important to attract engineering professionals who are working in other sectors, such as finance and business, back into the engineering environment where shortages are experienced (e.g into ESKOM, civil engineering and local government) by addressing salaries, working conditions and flexibility, especially to address women's needs with regard to planning of families and relocation.

The current increase in engineering enrolments at the universities and universities of technology is encouraging. However, the throughput rates to deliver engineering graduates are still low. Factors such as the poor quality of mathematics and science education at school level and the general low quality of the school system are challenges that need urgent attention if engineering skills shortages are to be addressed.

The significant number of people working in the engineering field without proper qualifications needs urgent attention and opportunities to get working experience need to be provided. Another issue is the underutilisation of those with an engineering 'related' qualification who are working in non-engineering occupations. There are quite a number of these people with engineering related qualifications and although it is not clear how many of these studied in a 'pure' engineering field, interventions, such as a transitional programme to retrain these people, provide them with experiential training where required, and a special wage dispensation to attract them back into the system, is recommended. An additional area of intervention is to address the training and certification of those with engineering 'related' fields of study and who are currently unemployed.

Various stakeholders such as ECSA, professional associations and large employers have proposed plans to address the engineering skills shortages in South Africa. Key among these, both in terms of scope and detail, is the work of Lawless (2005).

The establishment of JIPSA formalised the strategies to address the shortages of skills in general, but also specifically for engineering. Their focus is *inter alia* on developing and recruiting engineering and technical skills, and in the short-term, developing a graduate-employment strategy and recruiting retired specialist and expert mentors. Their interventions go so far as donating a significant monetary contribution to some universities to train more engineering professionals. However, tertiary institutions struggle to fill positions because remuneration of academics is only a third of what the private sector pays.[12] While the private sector supports JIPSA and some companies have contributed through training programmes and placements, much more remains to be done by private firms if compared globally (The Presidency 2008).

Lawless (2005) drafted a comprehensive list of interventions to address imbalances and blockages in the civil engineering profession over a longer period. These suggested interventions are applicable for all engineering professions. The recommendations arising out of this work are presented below. Notably these serve mainly to support rather than add to those of Lawless.

General education phase

The number of high-quality Grade 12 learners competent in Mathematics and Physical Science who can enroll for tertiary training can be increased by the following strategies:

- Improve numeracy from Grade 1 through to Grade 12 with appropriate syllabi
- Increase the number of high-quality Mathematics and Physical Science teachers by improving their salaries
- Improve the learning environment (schools) of learners by upgrading of infrastructure - the Department of Education is already investing close on R1 billion in 06/07 for infrastructure development in schools
- Increase the pool of competent black matriculants by identifying competent learners and giving them the opportunity to attend better schools
- Create awareness of the engineering profession and opportunities through coordinated nationwide career guidance initiatives at school level

Tertiary education and graduate training phase

The throughput rate and the number of competent engineering graduates entering the labour market can be increased by applying the following approach:

- Align supply and demand by disbursing higher subsidies to universities and universities of technology for scarce skills such as engineering
- Develop a standardised model for selection of engineering students in order to ensure suitable students enter engineering training at tertiary level
- Increase the investment in engineering students by providing sufficient bursary schemes that are sustainable for the duration of tertiary training
- Put monitoring systems in place to identify and address problems that students may encounter during the training period
- Provide students with access to additional resources and support such as tutors, role models in industry, etc.
- Review curricula to better align education and the needs of the workplace
- Improve the quality of staff and staff to student ratios

- Encourage companies to enlist more national diploma students on learnerships and provide them with the opportunity to do their one-year experiential training so that they can graduate (the wage subsidy incentive currently investigated by the Presidency may be one mechanism to encourage employers to provide experiential placments)
- Put efficient courses in place to assists graduates with their transition from education to work
- Encourage ECSA registration to ensure the continued development of young graduates
- Invest in and develop learnerships to ensure comprehensive workplace training for all engineering professionals
- Establish a framework for the transfer of knowledge from older engineering professionals to the younger cohorts

There are positive signs in the market in terms of education and training strategies. Some of the examples are the R543 million that Eskom spent on training in the 06/07 financial year.[70] Group Five's investment in training has almost doubled and its intake of students has tripled[71] and the SA Navy trains 650 technician recruits every year and many others are sponsored to study, says Johannes Mudimu, Navy Chief.[39]

Furthermore various government departments are currently offering bursary opportunities. The Department of Public Works is offering internship programmes to unemployed graduates with a B.Sc. in Mechanical, Structural, Civil and Electrical Engineering.[72] Municipalities are offering engineering bursaries such as the initiative of the infrastructure and engineering business unit of the Nelson Mandela Bay municipality – the unit currently provides bursaries to 22 civil engineering students.[73] The Western Cape provincial government has doubled the number of engineering bursaries.[10]

There is a multimillion-programme to train students in mechatronics – a combination of electronic and mechanical engineering – at three universities of technology. The programme has been endorsed by DTI.[74] This will provide skills development in this field of engineering. Students will, in addition to their theoretical training, receive in-service training of between eight and 12 months in industrial companies. The programme will produce almost 2 000 specialists in this field. General Motors South Africa invested R1 million in the establishment of the Advanced Mechatronic Technology Centre. This will allow students in the

70 Addressing skills shortage in engineering field *Star* 23.05.2007

71 Infrastructure spending is not on target – Group Five *Business Report* 14.07.2007

72 The big job call-up *Star* 01.02.2007

73 Bursaries address shortage of skills *The Herald* 19.04.2007

74 Offset programme gives birth to engineering course *Star* 22.11.2006

field to receive high quality training in the automotive sector – a good example of business providing the tertiary sector with support.[75]

Professional phase

There are numerous strategies that can be applied in this phase to attract and retain engineering professionals in the labour market, as well as those who are currently working in non-professional occupations.

<u>Remuneration</u>

"Our project and engineering skills are all going to Abu Dhabi if we don't start offering incentives for our skills to stay here. Money talks; I think that is a natural progression of life," says André Vermeulen, a facilitator of eDegree's project management programme and a lecturer at the University of Johannesburg.[76]

The salaries and employment conditions of engineering professionals must be reviewed, especially at municipal level. Meaningful tax rebates could also be granted to engineering professionals in order to stem the outflow to other countries. Introducing a scarce skills allowance can also attract and retain engineering professionals in the labour market.

<u>Dual career paths</u>

The approach of dual career paths at organisations also responds well to retention of technical skills. This approach creates a dual career path i.e. an engineering professional can have the same benefits and promotion opportunities either working as a manager or as a technical expert. In this way an engineering professional doing technical work could be on the same level of work and remuneration as a manager.

<u>Flexibility, especially for women</u>

In the case of women engineering professionals it is often found that work-life balance is more sought after than pay increases. Better employment arrangements and conditions should be offered to women engineering professionals such as part-time and flexible working hours or even career breaks.

<u>Open up immigration</u>

The importation of skilled professionals not only assists in dealing with shortages it also allows for skills transfer,[77] but South African policies and practices do not make it easy to immigrate to this country.

The publication of the skills quotas that allows the issuing of permits *inter alia* to engineering professionals who enter the country without a formal job offer is supposed to source and attract skills form the international community. However, according to stakeholders this process is very cumbersome. Furthermore the category 'science and engineering' is divided into 32 sub-categories and 5 000

75 General Motors to invest R1m in future engineers *The Herald* 31.01.2007

76 *Sunday Times* 5.03.2006

77 Importation of skills generates new cycle of skills transfer *Star* 30.01.2007

places are allocated to civil engineers, but only 100 to chemical engineers (CDE 2007). Experience further shows that if the quota system is not driven by an aggressive recruitment strategy, only a limited number of the required skilled people will make use of the opportunity.

Recruitment of retired engineering professionals

The initiative to recruit retired engineering professionals at municipal level to serve as mentors and train graduates is coordinated by ECSA. This strategy is a good example of a home-grown solution and will facilitate the implementation of projects and develop capacity needed to sustain these projects.

Recruitment of SA engineering professionals abroad

There are a couple of initiatives striving to recruit expatriate engineering professionals abroad. *Homecoming Revolution* is an online initiative that encourages - and assists - South Africans living abroad to return home. The *Come Home Campaign*, an initiative of trade union movement Solidarity, in collaboration with the *Company for Immigration*, strives to bring South African's working abroad back to the country. They help "emigrants" find work in SA, register children born abroad, get immigration documents for spouses, have overseas qualifications evaluated locally, and more.

Create an employer brand / occupational brand

SA businesses are called on to attract and retain human capital. A key facet should be differentiation, a unique human resources value proposition and employer brand that can make a company both different and more competitive than other firms. The labour market should perceive the organization as employer of choice– Prof Frank Horwitz, UCT Graduate School of Business.[28] Organisations that employ engineering professionals should apply this human resources strategy in order to attract and retain the engineering skills they need.

Talent management approach

Engineering skills shortages are global. For South African companies to compete in this international labour market they must change their approach to offer conditions that will attract and retain engineering professional talent.

Moratorium on employment equity in engineering scarce skills

Although the role of employment equity criteria in rectifying the racial imbalances of the past is widely accepted, there are others who argue that transformation policies are contributing to the shortage of engineering professionals in this country. Various authoritative sources, Webster Ndodana, first black president of the South African Association of Consulting Engineers;[24] the South African Institute of Race Relations;[48] Ann Bernstein, executive director of the Centre for Development and Enterprise;[47] engineers seconded to struggling municipalities;[14] Dr Mamphela Ramphele, former managing director of the World Bank;[78] Marius Fransman, an ANC provincial executive member and MEC for Transport and

78 Employment equity policy 'not a holy cow' *Cape Times* 22.02.2008

Public Works;[10] and Allyson Lawless, first women president of the South African Institution of Civil Engineering (2005:251, 2007:79), indicate that restructuring and other measures associated with transformation have led to the exodus (either out of the public sector, or the profession or the country) of skilled engineers when they could be playing an important role including training and mentoring new black professionals. There should be an urgent and serious debate on a moratorium on employment equity in scarce skills. Senior staff need to be retained to address the current skills problem by shadowing junior engineers so they can learn from more experienced engineers and “We need to manage transformation responsibly by recognising and retaining exceptional engineering talent, irrespective of race or gender identity,” as indicated by Danai Magugumela, black women engineer and CEO of BKS Consulting Engineers.[19] To manage transformation responsibly is to have knowledgeable staff with experience to assure service delivery and the transference of skills.

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ANNEXURE A

Table 2.3(b): Graduation trends in different engineering fields, 1996-2005

Fields of study	Rank	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	Total	% Average annual growth
Electrical	1	1538	1488	1503	1347	1176	1388	1610	1785	1917	2150	15902	3.79
Undergraduates	1	1412	1317	1349	1157	971	1164	1348	1517	1666	1890	13791	3.30
Technician	1	742	745	754	733	439	644	777	890	1028	1179	7932	5.27
Technologist	2	169	139	139	95	90	135	159	155	207	264	1551	5.11
Engineer	1	501	433	456	328	442	386	412	471	431	447	4308	-1.25
Postgraduates	1	126	171	154	191	205	223	263	268	250	260	2111	8.37
Civil	2	817	747	767	774	722	781	861	843	1004	1015	8331	2.44
Undergraduates	2	725	648	683	694	639	674	731	720	875	898	7285	2.40
Technician	2	371	285	341	426	395	348	397	435	542	566	4106	4.79
Technologist	1	182	179	187	135	94	148	151	139	186	209	1608	1.51
Engineer	4	171	184	155	132	150	178	184	147	147	123	1571	-3.60
Postgraduates	2	92	99	84	80	83	107	130	124	129	118	1046	2.74
Mechanical	3	871	849	763	623	559	705	688	707	764	855	7385	-0.20
Undergraduates	3	803	754	702	524	453	603	587	610	616	743	6395	-0.86
Technician	3	362	355	337	223	129	222	250	281	278	397	2833	1.04
Technologist	3	170	147	123	90	79	98	69	89	83	105	1052	-5.21
Engineer	2	271	252	242	210	246	283	268	241	256	241	2509	-1.31
Postgraduates	3	69	95	61	99	106	102	100	98	148	113	991	5.68
Chemical	4	551	462	525	356	532	600	581	620	744	760	5731	3.63
Undergraduates	4	496	422	459	305	437	516	498	541	664	640	4977	2.87
Technician	4	228	182	180	96	146	223	235	230	336	278	2135	2.23
Technologist	4	83	73	56	48	53	80	64	113	135	120	825	4.18
Engineer	3	184	167	223	160	239	213	200	199	192	241	2017	3.03
Postgraduates	4	56	40	65	51	95	84	83	78	80	121	754	8.97
Industrial	5	410	467	327	268	235	274	288	314	391	456	3430	1.19
Undergraduates	5	347	397	264	197	154	201	208	233	309	372	2680	0.77
Technician	5	226	257	147	62	35	49	47	64	88	97	1072	-8.99
Technologist	5	55	70	38	43	42	58	84	83	151	170	793	13.44
Engineer	5	67	70	79	92	77	93	76	86	70	106	816	5.23
Postgraduates	5	63	71	63	71	81	74	80	81	82	84	750	3.27
Mining	6	169	191	252	165	106	95	97	106	142	231	1553	3.57
Undergraduates	7	125	142	172	99	42	39	47	53	65	156	940	2.49
Technician	8	32	47	56	31	2	6	14	18	22	49	277	4.85
Technologist	6	62	65	85	24	0	0	0	0	0	57	293	-0.93
Engineer	6	31	30	31	44	40	33	33	35	43	50	370	5.46
Postgraduates	6	44	49	80	66	64	56	50	53	78	75	613	6.24
Metallurgical	7	152	114	113	90	101	120	90	116	138	237	1272	5.06
Undergraduates	6	137	95	102	78	85	108	77	100	111	196	1089	4.03
Technician	7	75	45	55	44	42	53	40	62	60	110	587	4.36
Technologist	7	19	20	21	23	24	32	21	24	42	58	284	13.20
Engineer	8	43	30	25	11	19	23	16	14	9	28	218	-4.76
Postgraduates	8	15	19	11	12	17	12	13	16	27	41	182	12.06
Materials	8	97	101	130	106	72	77	91	89	96	106	965	1.00
Undergraduates	9	71	78	98	66	38	50	68	65	83	79	697	1.21

Technician	9	33	39	66	12	10	15	20	10	22	20	246	-5.44
Technologist	8	28	28	23	43	13	22	36	32	28	30	283	0.77
Engineer	9	10	11	9	12	16	13	12	24	33	29	169	12.63
Postgraduates	7	26	23	32	39	34	27	23	24	13	27	268	0.40
Surveying	9	128	116	91	110	100	73	70	77	72	86	924	-4.28
Undergraduates	8	116	110	81	108	83	68	67	75	69	83	859	-3.60
Technician	6	75	78	54	87	64	53	49	51	43	63	616	-1.81
Technologist	12	17	4	2	6	3	4	8	12	16	7	80	-9.54
Engineer	10	24	28	25	15	16	11	10	11	10	13	163	-6.60
Postgraduates	12	12	6	10	2	17	6	4	3	4	3	65	-14.35
Computer	10	47	48	102	3	15	13	60	111	179	151	729	13.91
Undergraduates	10	44	45	97	0	4	3	45	88	139	112	577	10.88
Technician	13	36	30	86	0	4	2	0	0	0	0	158	0
Technologist	13	8	15	11	0	0	1	5	8	14	1	63	-20.63
Engineer	7	0	0	0	0	0	0	40	80	125	111	356	*****40.31
Postgraduates	9	3	3	5	3	11	10	15	23	40	40	152	34.08
Engineering Mechanics	11	0	0	0	65	67	14	133	65	102	91	536	***5.63
Undergraduates	11	0	0	0	60	67	14	131	63	101	85	520	***5.82
Technician	8	0	0	0	34	53	1	94	12	56	28	277	***-3.36
Technologist	9	0	0	0	26	14	14	37	50	37	48	226	***10.47
Engineer	13	0	0	0	0	0	0	0	0	8	9	17	******12.50
Postgraduates	15	0	0	0	5	0	0	2	2	1	6	16	***3.09
Environmental Engineering	12	0	0	0	52	57	59	39	48	43	20	318	***-15.01
Undergraduates	16	0	0	0	24	26	32	27	34	29	11	181	***-12.38
Technician	15	0	0	0	10	8	9	16	20	12	0	75	0
Technologist	11	0	0	0	13	18	23	11	14	17	11	106	***-3.63
Engineer	17	0	0	0	0	0	0	0	0	0	0	0	0
Postgraduates	10	0	0	0	29	31	28	12	14	14	9	136	***-17.56
Agriculture	13	32	35	21	26	22	33	26	35	33	34	297	0.50
Undergraduates	15	29	31	15	17	16	17	21	21	16	19	203	-4.82
Technician	17	6	9	2	15	0	1	6	7	3	5	55	-2.01
Technologist	16	0	7	0	0	0	5	2	1	1	0	15	0
Engineer	11	23	15	13	2	16	12	13	13	13	14	133	-5.68
Postgraduates	11	3	3	6	9	6	16	5	14	17	15	94	19.16
Marine	14	13	7	26	17	13	25	36	49	51	50	286	16.15
Undergraduates	12	13	7	26	16	13	25	36	49	51	50	285	16.15
Technician	12	12	6	23	11	10	20	26	17	22	25	171	8.50
Technologist	10	1	1	3	5	3	5	10	32	29	25	114	43.00
Engineer	17	0	0	0	0	0	0	0	0	0	0	0	0
Postgraduates	20	0	0	0	1	0	0	0	0	0	0	1	0
Bio-engineering	15	0	0	0	5	8	54	72	68	12	17	236	**22.63
Undergraduates	15	0	0	0	0	0	52	69	64	10	9	203	****-36.42
Technician	10	0	0	0	0	0	52	69	64	10	9	203	****-36.42
Technologist	20	0	0	0	0	0	0	0	0	0	0	0	0
Engineer	17	0	0	0	0	0	0	0	0	0	0	0	0
Postgraduates	14	0	0	0	5	8	2	3	4	2	9	33	**9.25
Graphics	16	0	0	0	75	11	4	21	29	29	60	229	**-3.77
Undergraduates	13	0	0	0	75	10	1	21	29	29	60	225	**-3.77
Technician	11	0	0	0	75	10	1	14	24	29	38	190	**-10.84
Technologist	15	0	0	0	0	0	0	7	5	0	22	34	*****46.48

Engineer	16	0	0	0	0	0	0	0	0	0	0	1	0
Postgraduates	19	0	0	0	0	1	3	0	0	0	0	4	0
Aerospace	17	84	57	14	5	5	5	7	11	16	9	211	-21.94
Undergraduates	14	83	54	13	5	4	4	7	11	16	9	206	-21.87
Technician	14	77	48	0	0	0	0	0	0	0	1	126	-38.29
Technologist	17	6	2	0	0	0	0	0	0	0	0	8	0
Engineer	12	0	4	13	5	4	4	7	11	16	8	72	*9.05
Postgraduates	18	1	3	1	0	1	1	0	0	0	0	5	0
Manufacturing	18	0	0	0	19	19	9	18	4	0	16	83	**-2.96
Undergraduates	17	0	0	0	16	17	8	18	4	0	16	78	**0.53
Technician	16	0	0	0	16	15	8	18	3	0	15	74	**-0.55
Technologist	18	0	0	0	0	2	0	0	0	0	1	3	***-12.94
Engineer	17	0	0	0	0	0	0	0	0	0	0	0	0
Postgraduates	17	0	0	0	4	2	1	0	0	0	0	6	0
Engineering Science	19	0	0	0	7	13	2	31	13	4	1	70	**-28.99
Undergraduates	18	0	0	0	3	0	0	27	3	3	35	70	**55.37
Technician	18	0	0	0	0	0	0	11	0	3	14	28	*****8.26
Technologist	14	0	0	0	0	0	0	16	3	0	19	37	*****4.96
Engineer	14	0	0	0	3	0	0	0	0	0	3	5	0
Postgraduates	13	0	0	0	4	13	2	4	10	1	1	35	**-23.01
Automotive	20	0	0	0	5	5	6			1	2	19	**-17.41
Undergraduates	20	0	0	0	3	0	0	0	0	1	2	6	**-8.91
Technician	20	0	0	0	3	0	0	0	0	0	0	3	0
Technologist	20	0	0	0	0	0	0	0	0	0	0	0	0
Engineer	15	0	0	0	0	0	0	0	0	1	2	3	******66.67
Postgraduates	16	0	0	0	2	5	6	0	0	0	0	14	0
Instrumentation	21	0	0	0	6	0	0	1	2	4	0	12	0
Undergraduates	19	0	0	0	6	0	0	1	1	0	0	7	0
Technician	19	0	0	0	6	0	0	0	0	0	0	6	0
Technologist	19	0	0	0	0	0	0	0	1	0	0	1	0
Engineer	17	0	0	0	0	0	0	0	0	0	0	0	0
Postgraduates	18	0	0	0	0	0	0	0	1	4	0	5	0
Geological engineering	22	0	0	1	2	1	0	0	0	0	1	5	0
Undergraduates	21	0	0	0	1	0	0	0	0	0	0	1	0
Technician	21	0	0	0	1	0	0	0	0	0	0	1	0
Technologist	20	0	0	0	0	0	0	0	0	0	0	0	0
Engineer	17	0	0	0	0	0	0	0	0	0	0	0	0
Postgraduates	19	0	0	1	1	1	0	0	0	0	1	4	0
Other Engineering & Engineering Technology		150	187	147	163	113	126	169	164	199	220	1639	4.36
Undergraduates		83	88	47	109	51	59	64	44	90	79	713	-0.57
Technician		56	63	39	61	23	5	21	9	11	32	318	-6.06
Technologist		12	7	3	12		16	8	13	8	2	81	-18.39
Engineer		15	19	4	36	27	38	36	23	70	45	314	13.07
Postgraduates		67	98	101	54	62	67	105	120	109	141	925	8.65
Total		5059	4870	4781	4289	3951	4463	4989	5255	5939	6568	50164	2.94
Total undergraduates		4483	4188	4108	3562	3109	3636	4097	4323	4941	5506	41952	2.31
Total postgraduates		576	682	673	728	842	826	892	932	998	1063	8212	7.05

*1997-2005; **1999-2005; ***2000-2005; ****2001-2005; *****2002-2005; ******2004-2005