

UNIVERSITY OF KWAZULU-NATAL

**ENGINEERING SKILLS SHORTAGE IN ESKOM:
AN ANALYSIS OF THE SITUATION AND AN ASSESSMENT OF THE
IMPACT OF CURRENT AND PROPOSED INTERVENTIONS**

**By
Brendan Moodley, Pr Eng
952014970**

**A dissertation submitted in partial fulfillment of the requirements for the degree
of
Master of Commerce
(Strategic Project Leadership and Management)**

**Leadership Centre
Faculty of Management Studies**

Supervisor: Professor RG Taylor

2008

DECLARATION

I, Brendan Moodley, declare that

- (i) The research reported in this dissertation/thesis, except where otherwise indicated, is my original research.
- (ii) This dissertation/thesis has not been submitted for any degree or examination at any other university.
- (iii) This dissertation/thesis does not contain other persons' data, pictures, graphs or other information, unless specifically acknowledged as being sourced from other persons.
- (iv) This dissertation/thesis does not contain other persons' writing, unless specifically acknowledged as being sourced from other researchers. Where other written sources have been quoted, then:
 - a) their words have been re-written but the general information attributed to them has been referenced:
 - b) where their exact words have been used, their writing has been placed inside quotation marks, and referenced.
- (v) This dissertation/thesis does not contain text, graphics or tables copied and pasted from the Internet, unless specifically acknowledged, and the source being detailed in the dissertation/thesis and in the References sections.

Signature:



ACKNOWLEDGEMENTS

The author wishes to acknowledge the following people for their valuable contribution to this research study:

Professor Robert G Taylor	Supervisor
Christoph Kohlmeyer	Interviewee
Johannes van Tonder	Interviewee
Clive Le Roux	Interviewee
Samantha Kali	Interviewee
Eugene Motsoatsoe	Interviewee
Zubair Moola	Interviewee
Dieter Huppe	Interviewee
Elsie Pule	Interviewee
John Gosling	Interviewee
My wife: Isaivani Moodley, Pr Eng	Proof Reader

In addition, the author would like to thank all other members of the Control & Instrumentation Department, Enterprises Engineering Department, Eskom for their valuable input during casual conversations and discussions on this research topic.

096805

ABSTRACT

South Africa currently finds itself in a constrained power supply environment. In order to alleviate this constraint, Eskom, the dominant (and state-owned) electricity supplier in South Africa has embarked on an electricity capacity expansion programme. One of the constraints on the capacity expansion programme, as identified by Eskom, is the shortage of skills including that of engineering skills.

Firstly, an understanding of the background to the shortage of engineering skills in South Africa and Eskom was gained through literature review. Thereafter, a list of contributors was identified in terms of the skills shortage in South Africa and Eskom. In addition to this local view of the engineering skills shortage issue, the author of this dissertation supplemented this with a review of international literature.

The issue was then documented using systems thinking diagramming techniques which eventually culminated in the development of a draft systems dynamics model of the shortage of engineering skills in Eskom for the capacity expansion effort. Once the draft system dynamics model was developed, the author of this dissertation conducted one-on-one interviews with staff members who represented the stakeholders in the engineering skills shortage issue for Eskom's capacity expansion programme. This enabled the author of this dissertation to share his understanding of the problem with the interviewees and to gain an improved understanding of the issue by listening to the interviewees. Thereafter, this improved understanding was utilised to update the systems dynamics model. Finally, this updated model was utilised to perform an analysis to determine the leverage points to alleviate the engineering skills shortage problem in Eskom's capacity expansion programme.

The literature survey suggested that mentorship, retention of current engineering skills and improving the image of engineering (in general) should be pursued to alleviate the shortage of engineering skills in the electricity industry. Furthermore, the use of interviews and systems dynamics modelling suggested that there needs to be a core focus on mentorship. In addition, effort should be allocated to attracting more of the under-represented groups into engineering i.e. women and black males. Furthermore, effort needs to be placed on specifying the capacity expansion resource requirements adequately i.e. plans in terms of numbers of people, qualifications and skill level are required. Finally, the interview process highlighted the view (not supported by systems dynamics modelling) that outsourcing of engineering work and importing of engineering skills should be pursued as a last resort.

KEY WORDS

Eskom, Engineering Skills Shortage, Capacity Expansion Programme

CONTENTS

	PAGE
LIST OF FIGURES	VI
LIST OF TABLES	VIII
LIST OF ACRONYMS	IX
CHAPTER 1 : INTRODUCTION.....	1
CHAPTER 2 : BACKGROUND.....	4
2.1 DEFINITION OF SKILL AND ENGINEERING SKILL.....	5
2.2 ESKOM’S HISTORY AND CURRENT STRUCTURE.....	8
2.3 CONTRIBUTORS TO THE SHORTAGE OF ENGINEERING SKILLS	11
2.3.1 <i>South African Economy Growth & The Supply of Engineering Skill</i>	11
2.3.2 <i>South African Education System</i>	13
2.3.3 <i>Loss of Current Engineering Skills</i>	13
2.3.4 <i>Inefficient utilisation of Engineering Resources</i>	14
2.4 INDUSTRY AND GOVERNMENT PARTNERSHIP TO DEVELOP SKILLS	16
2.5 ENGINEERING SKILL SHORTAGES IN ESKOM : CURRENT INITIATIVES	17
2.5.1 <i>Summary of current interventions within Eskom</i>	18
2.6 ENGINEERING SKILLS SHORTAGE: INTERNATIONAL EXPERIENCE	21
2.6.1 <i>Engineering Skill Migration</i>	21
2.6.2 <i>Engineering Skills: The Chinese Factor</i>	22
2.6.3 <i>The Role of Engineering in Developing Countries</i>	24
2.6.4 <i>The Industry/Academia Interface</i>	24
2.6.5 <i>Engineering Curricula</i>	26
2.6.6 <i>Engineering Skills Shortage: Factors Affecting Electricity Utilities in the USA</i>	29
2.6.7 <i>Skills Retention in South Africa and Globally</i>	32
2.6.8 <i>Women and Other Under-Represented Groups in Engineering</i>	34
2.6.9 <i>Marketing of Engineering</i>	38
CHAPTER 3 : RESEARCH MODEL & METHODOLOGY.....	40
3.1 RESEARCH MODEL	40
3.2 METHODOLOGY.....	41
3.2.1 <i>Justification of Systems Dynamics Modelling as a research tool</i>	43
3.2.1.1 Mental Models: The Draw-Backs.....	43
3.2.1.2 Systems Dynamics: Dealing With Dynamic Complexity	44
3.2.1.3 The Use of a Draft Systems Dynamics Model.....	45
3.2.1.4 The Use of an Updated Systems Dynamics Model.....	45
3.2.2 <i>Interviewee Selection</i>	46

CHAPTER 4 : DATA SUMMARY AND ANALYSIS.....	48
4.1 DRAFT SYSTEMS DYNAMICS MODEL DEVELOPMENT	50
4.1.1 Rich Picture.....	50
4.1.2 Systems Map.....	53
4.1.3 Influence Diagram	54
4.1.4 Multiple Cause Diagram.....	56
4.1.5 Draft Systems Dynamics Model	57
4.1.5.1 The use of itthink.....	59
4.1.5.2 A Description of the Draft Systems Dynamics Model.....	60
4.2 SUMMARY OF INTERVIEW DATA	78
4.2.1 Perspectives on the Impact of Current Interventions	80
4.2.2 Proposed Interventions	82
4.3 UPDATED SYSTEMS DYNAMICS MODEL AFTER INTERVIEWS.....	88
4.3.1 Updated Systems Dynamics Model	88
4.3.2 Analysis of Updated Systems Dynamics Model.....	90
CHAPTER 5 : CONCLUSIONS & RECOMMENDATIONS.....	96
REFERENCES.....	100
APPENDIX 1: LIST OF QUESTIONS PER INTERVIEWEE	108
APPENDIX 2: DETAILS OF SYSTEMS DYNAMICS MODELS	110
DETAILS OF DRAFT SYSTEMS DYNAMICS MODEL	110
Stocks & Flows of Draft Systems Dynamics Model.....	110
Black Male Maths and Science Students	110
Black Male Engineering Students.....	111
Black Male Matriculants.....	111
ECSA Recognised Professionals in Eskom	112
Engineering Graduates in Eskom.....	113
Engineering Skills in Eskom for Capacity Expansion	114
Engineering Skills in Eskom for other uses eg operations & maintenance	115
Engineering Graduates.....	116
Female Engineering Students	117
Female Maths & Science Students.....	117
Female Matriculants	118
International Companies utilising engineering skills	118
South African Engineering Companies.....	119
White Male Maths & Science Students	120
White Male Matriculants	120
White Male Engineering Students	121
DETAILS OF UPDATED SYSTEMS DYNAMICS MODEL.....	122
APPENDIX 3: ANALYSIS OF UPDATED SYSTEMS DYNAMICS MODEL.....	128

APPENDIX 4: SUMMARY OF INTERVIEWEES' RESPONSES 134

ENGINEER IN TRAINING: CHRISTOPH KOHLMEYER..... 134

CHIEF ENGINEER: JOHANNES VAN TONDER 138

SENIOR GENERAL MANAGER (NUCLEAR PROGRAMME): CLIVE LE ROUX 143

ENGINEER: SAMANTHA KALI 147

SENIOR TECHNICIAN: EUGENE MOTSOATSOE 151

ENGINEER: ZUBAIR MOOLA 155

CONTROL & INSTRUMENTATION MANAGER: DIETER HUPPE 158

HUMAN RESOURCES SHARED SERVICES MANAGER: ELSIE PULE 161

LEADERSHIP AND PROFESSIONAL DEVELOPMENT MANAGER: JOHN GOSLING 166

LIST OF FIGURES

	PAGE
FIGURE 1	ESKOM'S ORGANISATIONAL STRUCTURE..... 10
FIGURE 2	NUMBER OF UNIVERSITY ENGINEERING GRADUATES PER YEAR IN SOUTH AFRICA..... 12
FIGURE 3	NUMBER OF UNIVERSITY ENGINEERING GRADUATES PER YEAR IN SOUTH AFRICA..... 23
FIGURE 4	PROPOSED COMPONENTS OF AN ENGINEERING CURRICULUM..... 26
FIGURE 5	VENN DIAGRAM OF PERSONAL, PROFESSIONAL AND INTERPERSONAL SKILLS..... 27
FIGURE 6	SOUTH AFRICAN WOMEN ENGINEERING GRADUATES..... 36
FIGURE 7	SOUTH AFRICAN BLACK MALE ENGINEERING GRADUATES..... 36
FIGURE 8	PERCENTAGE SCIENCE, ENGINEERING & TECHNOLOGY ENROLLMENTS IN HIGHER EDUCATION INSTITUTIONS IN SOUTH AFRICA..... 38
FIGURE 9	METHODOLOGY UTILISED TO UNDERSTAND THE PROBLEM AND TO DETERMINE INTERVENTIONS 41
FIGURE 10	SYSTEMS MAP OF ENGINEERING SKILLS IN ESKOM 46
FIGURE 11	RICH PICTURE OF THE ABILITY OF THE ENGINEERING SECTOR TO ATTRACT STUDENTS..... 50
FIGURE 12	SYSTEMS MAP OF ENGINEERING SKILLS IN ESKOM 53
FIGURE 13	INFLUENCE DIAGRAM OF ENGINEERING SKILLS IN ESKOM 55
FIGURE 14	MULTIPLE CAUSE DIAGRAM FOR THE SHORTAGE OF ENGINEERING SKILLS IN ESKOM..... 56
FIGURE 15	DRAFT SYSTEMS DYNAMICS MODEL DEPICTING THE ENGINEERING SKILLS IN ESKOM..... 58
FIGURE 16	ENGINEERING SKILLS IN ESKOM FOR THE CAPITAL EXPANSION PROGRAMME 72
FIGURE 17	SYSTEM DYNAMICS MODEL: NUMBER OF STUDENTS AND GRADUATES 74
FIGURE 18	SYSTEM DYNAMICS MODEL: PERCENTAGE OF STUDENTS AND GRADUATES 74
FIGURE 19	ACTUAL FIGURES OF STUDENTS AND GRADUATES..... 75
FIGURE 20	ACTUAL ⁴⁶ PERCENTAGE FIGURES OF STUDENTS AND GRADUATES..... 76
FIGURE 21	COMPARISON: SYSTEMS DYNAMICS MODEL VERSUS ACTUAL 77
FIGURE 22	SUMMARY OF THE CATEGORISATION OF ALTERNATIVE INTERVENTIONS..... 87
FIGURE 23	UPDATED SYSTEMS DYNAMICS MODEL DEPICTING THE ENGINEERING SKILLS IN ESKOM 88
FIGURE 24	UPDATED SYSTEMS DYNAMICS MODEL: BASE CASE..... 90
FIGURE 25	UPDATED SYSTEMS DYNAMICS MODEL: MENTORSHIP PROGRAMME = +1%..... 92
FIGURE 26	UPDATED SYSTEMS DYNAMICS MODEL: MENTORSHIP PROGRAMME = +10%..... 93
FIGURE 27	ESKOM MATRIC TEACHER AND STUDENT SUPPORT = +20% 128
FIGURE 28	ESKOM FINANCIAL SUPPORT PROGRAMME = +20% 128
FIGURE 29	ESKOM ENGINEERING PROMOTION AT SCHOOLS = +20% 129
FIGURE 30	ENGINEERING ATTRACTIVENESS TO TERTIARY ENROLLMENTS[WHITE MALE] = +5% 129
FIGURE 31	ENGINEERING ATTRACTIVENESS TO TERTIARY ENROLLMENTS[BLACK MALE] = +20% 130
FIGURE 32	ENGINEERING ATTRACTIVENESS TO TERTIARY ENROLLMENTS[FEMALE] = +20%..... 130
FIGURE 33	EFFECTIVENESS OF ESKOM TERTIARY SUPPORT INITIATIVES = +10% 131
FIGURE 34	RECRUITMENT AGGRESSIVENESS = +10% 131
FIGURE 35	MULTIPLE VARIABLES TAKEN INDIVIDUALLY = +10% 132

FIGURE 36 ESKOM INTERNATIONAL MARKETING INITIATIVES = +75%..... 132

FIGURE 37 ESKOM CAPITAL EXPANSION RELATIVE INTERNAL SALARY= +10%..... 133

LIST OF TABLES

		PAGE
TABLE 1	ELEMENTS OF THE COGNITIVE DOMAIN OF BLOOM'S TAXONOMY	6
TABLE 2	DESCRIPTION AND CLASSIFICATION OF CURRENT INTERVENTIONS.....	20
TABLE 3	PROBABLE CAUSES: LACK OF TECHNICAL RESOURCES IN THE ELECTRICITY INDUSTRY.....	29
TABLE 4	INTERVENTIONS TO ALLEVIATE TECHNICAL RESOURCE SHORTAGE IN THE ELECTRICITY INDUSTRY.	30
TABLE 5	GENDER DIFFERENCES IN MATHEMATICS AND SCIENCE PARTICIPATION.....	35
TABLE 6	NARRATIVE OF METHODOLOGY PRESENTED IN FIGURE 9	42
TABLE 7	LIST OF INTERVIEWEES	47
TABLE 8	NARRATIVE OF THE METHODOLOGY UTILISED TO ARRIVE AT A DRAFT SYSTEM DYNAMICS MODEL	48
TABLE 9	SUMMARY OF <i>ITHINK</i> MODEL ELEMENTS UTILISED IN FIGURE 15.....	59
TABLE 10	SUMMARY OF EQUATIONS AND INITIAL VALUES OF THE STOCKS AND FLOWS	63
TABLE 11	SUMMARY OF EQUATIONS AND CONSTANTS OF THE CONVERTERS	71
TABLE 12	INTERVIEW PROCESS PER INTERVIEWEE	78
TABLE 13	OTHER CURRENT INTERVENTIONS IDENTIFIED BY INTERVIEWEES	79
TABLE 14	SUMMARY OF PERCEIVED IMPACT OF CURRENT INTERVENTIONS UNDERTAKEN BY ESKOM.....	80
TABLE 15	ESKOM'S 7-Bs RESOURCING STRATEGY.....	82
TABLE 16	CATEGORISATION OF THE ALTERNATIVE INTERVENTIONS ACCORDING TO ESKOM'S 7-Bs	86
TABLE 17	SUMMARY OF ANALYSIS OF CHANGES TO ESKOM-CONTROLLABLE VARIABLES.....	94
TABLE 18	LIST OF QUESTIONS PER INTERVIEWEE	109
TABLE 19	INTERVIEW SUMMARY: CHRISTOPH KOHLMEYER.....	137
TABLE 20	INTERVIEW SUMMARY: JOHANNES VAN TONDER.....	142
TABLE 21	INTERVIEW SUMMARY: CLIVE LE ROUX.....	146
TABLE 22	INTERVIEW SUMMARY: SAMANTHA KALI.....	150
TABLE 23	INTERVIEW SUMMARY: EUGENE MOTSOATSOE	154
TABLE 24	INTERVIEW SUMMARY: ZUBAIR MOOLA.....	157
TABLE 25	INTERVIEW SUMMARY: DIETER HUPPE.....	160
TABLE 26	INTERVIEW SUMMARY: ELSIE PULE.....	165
TABLE 27	INTERVIEW SUMMARY: JOHN GOSLING	171

LIST OF ACRONYMS

AsgiSA	Accelerated and Shared Growth Initiative for South Africa
BoT	Behaviour over Time
C&I	Control and Instrumentation
DoE	Department of Education
DoPE	Department of Public Enterprises
DoPW	Department of Public Works
DoL	Department of Labour
DTI	Department of Trade and Industry
ECSA	Engineering Council of South Africa
ED	Enterprises Division
EED	Enterprises Engineering Department
GARP	Grading, Assessment and Remuneration Programme
HR	Human Resources
ICT	Information and Communication Technology
JIPSA	Joint Initiative for Priority Skills Acquisition
JV	Joint Venture
KPI	Key Performance Indicator
MDG	Millenium Development Goal
NPD	Nuclear Programme Department
O&M	Operating and Maintenance
OCGT	Open Cycle Gas Turbine
OECD	Organisation for Economic Co-operation and Development
SETA	Sector Education and Training Authority
SOE	State-Owned Enterprise
SPV	Special Purpose Vehicle
TASK	Tuned Assessment of Skills and Knowledge
VFTPC	Victoria Falls and Transvaal Power Company

CHAPTER 1 : INTRODUCTION

In order to meet the soaring South African electricity demand, the capacity of the national electricity supply grid is currently being increased through an expansion programme lead by state-owned electricity utility, Eskom. Eskom, which currently provides 95% of South Africa's electricity demand considered various options in the mid-1990s to expand its electricity supply capacity, one of which (already undertaken) is the return to service of three mothballed power stations, namely Camden, Grootvlei and Komati.

In addition, in Eskom's 2006 annual report, it has been noted that the designing and building of new power stations has already been undertaken. The most significant are the Open Cycle Gas Turbines (OCGTs) at Atlantis and Mosselbay where some units have achieved commercial load¹ prior to mid-2007, the coal-fired Medupi power station where it is expected that commercial load will be after 2011 and the Ingula pump storage scheme with an expected commercial load after 2012. Furthermore, Eskom has noted in its 2007 annual report that there are also plans to increase South Africa's nuclear power generation base.

To meet South Africa's growing energy demands, Eskom is expected to spend in excess of R150 billion in the next 5 years on building new supply capacity. It has been noted by Perkins *et al* (2005) that an estimated 12000 Megawatts of peak generation capacity will be needed for the next 20 years, excluding the capacity provided by the return to service of the mothballed plants. This figure has been revised to 20000 Megawatts, which is essentially an increase of 50% of the current power generation capacity in South Africa.

However, one of the severe constraints on the power generation capacity expansion programme is the shortage of engineering skills in South Africa as noted in Eskom's 2006 annual report and in an internal human resources magazine, Eskom (2005b). In Eskom's 2008 annual report, the figure quoted in terms of the requirement for additional skills, including engineering, is 1431 additional people for 2009 and rises to a cumulative total of 2958 additional people in 5 years time. In addition, the figures quoted in the 2008 Eskom annual report is that there was a net gain of 2208 employees in the previous financial year. This net gain was a result of the recruitment of 4385 people and a loss of 1817 people through resignations and retirements².

¹ Commercial load is when the power generating unit is providing power onto the national electricity transmission grid for associated revenue.

² The rest of the losses are made up through deaths and dismissals which total 360 people.

The consequences of not having the required number of engineering resources to support the power generation capacity expansion programme would be that the demand for electricity would outstrip the supply of electricity and hence the result would be that the shortage of electricity generation capacity will be exacerbated. This shortage of electricity generation capacity could further result in stunted if not negative economic growth in South Africa, due to either existing companies not being able to produce their products or services or new companies being deterred from investing in South Africa due to the prospect of a shortage of electricity.

The ultimate objective of this dissertation is to provide recommendations as to which interventions Eskom must pursue in order to alleviate the shortage of engineering skills with respect to its power generation capacity expansion programme.

The process used to meet the above-mentioned objective was to firstly analyse Eskom's engineering skills shortage situation with respect to its power generation capacity expansion programme. This analysis was supported by a literature study. Thereafter, the impact of current and proposed interventions to relieve this engineering skills shortage in Eskom was assessed. Finally, through the use of systems dynamics modelling, the most effective interventions that Eskom could take were identified.

This research considers the shortage of engineering skill with respect to Eskom's power generation capacity expansion programme. More specifically, it excludes those shortages of engineering skill found in the operations and maintenance environments of Eskom. In addition to the above limitations, the systems dynamics model presented makes use of some simplifications and therefore does not represent all the complexities of the real situation. These simplifications are described in the dissertation.

The layout of the dissertation is as follows:

Chapter 2 firstly provides a definition of skill and specifically engineering skill with respect to Eskom's capacity expansion programme. Thereafter, a background to the shortage of engineering skills in South Africa and Eskom is provided. In addition, a discussion of contributors to the shortage of engineering skills in South Africa as well as international experience is provided and includes a discussion on skill retention.

Chapter 3 thereafter elaborates on the research model and methodology, which makes use of systems thinking and the tightly coupled sub-field of systems dynamics modelling. In order to provide a richer picture of the situation to be modelled using systems dynamics modelling, the author of this dissertation interviewed a number of stakeholders within Eskom.

Chapter 4 then describes the process utilised in data gathering and subsequently provides a summary and an interpretation of the data.

Finally, conclusions and recommendations are provided as to how Eskom can alleviate the risk of the shortage of engineering skills on its power generation capacity expansion programme.

CHAPTER 2 : BACKGROUND

This chapter firstly provides a description of the concept of skill and more specifically engineering skill in Eskom for its power generation capacity expansion programme. This is followed by a history of Eskom and the current organisational structure. This organisational structure is used to depict where the engineering resources for the power generation capacity expansion programme reside.

This is then followed by a discussion of the contributors to the shortage of engineering skills in Eskom for the power generation capacity expansion programme. Thereafter, due to the far reaching consequences of policies and legislation that is enforced by government, a description of the partnership between government and industry is provided. Finally, a description of the current effort by Eskom and international companies to alleviate engineering skills shortage is provided.

2.1 DEFINITION OF SKILL AND ENGINEERING SKILL

De Cronje *et al* (2004) state that in order to satisfy society's (unlimited) needs, organisations have to make use of limited resources. The limited resource of concern to this research study is the dimension of engineering skill needed for Eskom's power generation capacity expansion programme.

Human resources from a business management perspective includes "the physical and mental talents and skills of people employed to create products and services" and it has been stated that in order for "... the manufacturing process of any country to be of any value, its labour force has to be trained for certain periods to certain levels of skill", De Cronje *et al* (2004).

Although the concepts of talent and skill are widely used in everyday language, they each mean different things to different people. Talent can be defined as "natural ability or power" Collins (1992) and "recurring pattern of thought, feeling or behaviour that can be productively applied", Ebben (2006). To the layman, skill has been defined as the "ability to do something well", Microsoft (1999). In addition to this definition, Attewell (1990) states that skill "...encompasses both mental and physical proficiency". However, he goes on further to state that the physical proficiency part of skill is not given much emphasis as compared to the mental part of skill. Additionally, Attewell (1990) states that the historical analysis of the origin of skill as a word shows that it "...also connotes a dimension of increasing ability".

Furthermore, Rigby & Sanchis (2006) presents an argument that the "concept of skill needs to begin with an appreciation of its social construction". This social constructivist view is presented as one of four views³ on the concept of skill by Attewell (1990) and is used to develop the definition of engineering skill in this dissertation.

Hoag (2001) refers to Bloom's Taxonomy⁴, which divides educational objectives into three domains, namely affective⁵, psychomotor⁶, and cognitive⁷. The cognitive domain, Huitt (2004) and Krumme (2005), is made up of six elements as presented in Table 1.

³ The other views being Positivist, Ethnomethodological and Marxist. The discussion of these views is not relevant to this dissertation and is therefore not presented.

⁴ Taxonomy of Educational Objectives, mostly referred to as Bloom's Taxonomy, is a classification of the different objectives and skills that educators set for students.

⁵ Skills in the affective domain essentially describe the way people react emotionally.

#	Cognitive Elements	Description
1	Knowledge	Remembering of previously learned information.
2	Comprehension	Understanding of the information that is known.
3	Application	Use of "...previously learned information in new and concrete situations to solve problems that have single or best answers", Krumme (2005).
4	Analysis	"...[B]reaking down of informational materials into their component parts, examining (and trying to understand the organizational structure of) such information to develop divergent conclusions by identifying motives or causes, making inferences, and/or finding evidence to support generalizations", Krumme (2005).
5	Synthesis	"Creatively or divergently applying prior knowledge and skills to produce a new or original whole.", Krumme (2005).
6	Evaluation	"Judging the value of material based on personal values/opinions, resulting in an end product, with a given purpose, without real right or wrong answers.", Krumme (2005).

Table 1 Elements of the Cognitive domain of Bloom's Taxonomy

The author of this dissertation summarises the above concepts of skill as "the increasing ability to utilise both mental and physical proficiencies to do something well". It must be noted that the "something well" part is derived from its social construction i.e. society determines what the measures are when assessing how "well"⁸ something is accomplished and hence the perceived level of skill.

In terms of engineering skill, the obvious question is then to ask: *What is this "something" that the engineer does?* Starr (2004) offers the following definition: "Engineers use math[ematics] and science to design new artifacts and technologies that may be used to

⁶ Skills in the psychomotor domain describe the ability to physically use a tool or instrument.

⁷ Skills in the cognitive domain revolve around knowledge, the understanding and application thereof.

⁸ The word "well" could include both effectiveness and efficiency. Whilst society might not be able judge the efficiency of the system, society will (in most cases) be able to determine whether the system is meeting their needs i.e. they are able to determine what the effectiveness of the system is in meeting their needs.

solve practical problems.” Using this definition⁹, engineers are therefore required to utilise all six cognitive elements as presented in Table 1 in order to perform their role.

In South Africa, the engineering profession is regulated by the Engineering Council of South Africa (ECSA) under the Engineering Profession Act, Republic of South Africa (2000). In terms of this act, the following four professional categories are recognised (according to their level of responsibility in engineering-related work):

1. Professional Engineer
2. Professional Engineering Technologist
3. Professional Certificated Engineer
4. Professional Engineering Technician

In the Enterprises Division of Eskom, the requirement is to utilise people who are registerable or registered in one of the above four categories. A registration of a person in one of these four categories gives assurance to the employer and the public at large that the person is competent in their field of practice. In essence, the person has progressed through higher levels of responsibility and gained experience in their field of practice. This is important when considering the magnitude of the projects being undertaken (coal-fired stations in excess of R80 billion each).

The complexity of the engineering design work that the Enterprises Division performs, requires that skills from multiple engineering disciplines be utilised:

1. Chemical
2. Civil
3. Mechanical
4. Electrical
5. Electronic

Therefore, to summarise, in this dissertation the term “engineering skill” in Eskom will refer to that engineering skill as defined above, that is required by Enterprises Division to fulfill their mandate¹⁰. Artisans are excluded from this research study.

⁹ The reader is referred to Trevelyan (2006) for a more comprehensive definition of the various roles that an engineer can perform.

¹⁰ Delivering refurbishment, return to service and new-build projects as defined by Eskom (2005a).

2.2 ESKOM'S HISTORY AND CURRENT STRUCTURE

In 1906, the Victoria Falls and Transvaal Power Company (VFTPC) was established by a consortium of British and German companies doing business in Southern Africa. Electricity demand from the gold mines in the Republic of South Africa resulted in rapid growth, and Eskom (previously the Electricity Supply Commission, or Escom) was established by government in 1923 as a means of supplying electricity at cost, as noted by Perkins *et al* (2005).

The VFTPC was nationalised in 1948, during which time Eskom expanded its capacity to meet growing electricity demand (e.g. from the development of the Free State goldmines in the 1950s). In addition, municipalities discontinued electricity production as they found it cheaper to purchase electricity from Eskom, leaving Eskom as a virtual monopoly of electricity generation and transmission in South Africa.

Eskom's 2006 annual report demonstrates that it is the dominant electricity supplier on the African continent with it ranking around the top 10 electricity suppliers internationally in terms of size (11th) and sales (7th). Furthermore, the 2006 annual report also states that Eskom supplies around 95% of South Africa's electricity requirements and just under 50% of Africa's electricity requirements. In addition, Eskom is one of the lowest-cost power producers in the world (a price of ~4 US cents per kWh is quoted by an extract in Eskom 2006 annual report of the April 2005 NUS Consulting Group International Electricity Survey and Cost Comparison).

Perkins *et al* (2005) note that although annual growth in electricity demand was strong in the years prior to the 1980s, the 1980s saw a down-turn during which it slowed to 2.3% from 6.1%. This resulted in an excess in generation capacity and a number of power plants were subsequently mothballed, namely Komati, Camden and Grootvlei (total of 3800 Megawatts, approximately 10 % of the current electricity grid size). No large-scale power generation projects were undertaken during this period and hence engineering skills for capacity expansion projects were not needed. At the same time, Eskom embarked on a down-sizing programme that took Eskom's staff compliment from ~80000 people to ~32000 people.

However, in the 1990s Eskom embarked on an electrification programme to expand its services to areas which had been neglected during apartheid. Perkins *et al* (2005) states that this resulted in the peak demand growing from 23 169 Megawatts in 1993 (62% of capacity) to 31 928 Megawatts in 2003 (approximately 80% of capacity), an average

growth rate of 3.3% per annum. Although there were other contributors to the increase in demand such as large industrial business, the issue of the increase in the peaks in demand experienced in the morning and afternoon are largely attributable to domestic consumption.

On the other hand, Eskom's total power station net maximum capacity was relatively stable in the period 1993-2002 (ranging from around 36 000 Megawatts to around 40 000 Megawatts). With this rate of growth and the need for a greater reserve margin, the current capacity has been found to be inadequate to meet peak demand in the first instance of January of 2007 albeit under extenuating circumstances¹¹.

With this problem at hand, Eskom considered various options in the mid-1990s to expand its electricity supply capacity, one of which (already undertaken) is the return to service of three mothballed power stations, namely Camden, Grootvlei and Komati as described in Eskom's 2006 annual report.

The South African government's Department of Minerals and Energy (1998) Energy Policy White Paper, set the scene for a reform of the electricity sector, in which new power stations will be required. This white paper stated that Eskom will be expected to meet some 70% of the country's future power needs, with the remaining 30% to be provided by the private sector. However, this requirement of 30% from the private sector proved in hindsight to be unrealistic and was partly due to foreign investment in electricity industries being reduced worldwide, Thomas (2004).

However, Eskom has gone ahead with the designing and building of new power stations in addition to the re-powering of the mothballed stations. The most notable are the Open Cycle Gas Turbines at Atlantis and Mosselbay with commercial load prior to mid-2007, the coal-fired Medupi Power Station with commercial load anticipated in 2011 and the Ingula pump storage scheme with anticipated commercial load in 2012.

To meet South Africa's growing electricity demands, Eskom is expected to spend in excess of R150 billion in the next 5 years on building new supply capacity. It has been stated that an estimated 20 000 Megawatts of peak generation capacity will be needed for the next 20 years, excluding the capacity provided by the return to service of mothballed plants.

¹¹ A number of power generating units in Mpumalanga had unplanned outages at this stage.

In 2002, Eskom was converted from a statutory body to a public company (Eskom Holdings Limited) with the South African government as the sole shareholder. The structure of Eskom is depicted in Figure 1 taken from Eskom’s 2006 annual report, in which it must be noted that the acquisition of electricity infrastructure for the expansion of Eskom’s electricity supply capacity will be done through the highlighted Enterprises division. Although the other divisions house engineering skill for the maintenance and operational requirements, the Enterprises division houses the key human resources, including engineering and project management skills, needed for the power generation capacity expansion programme.

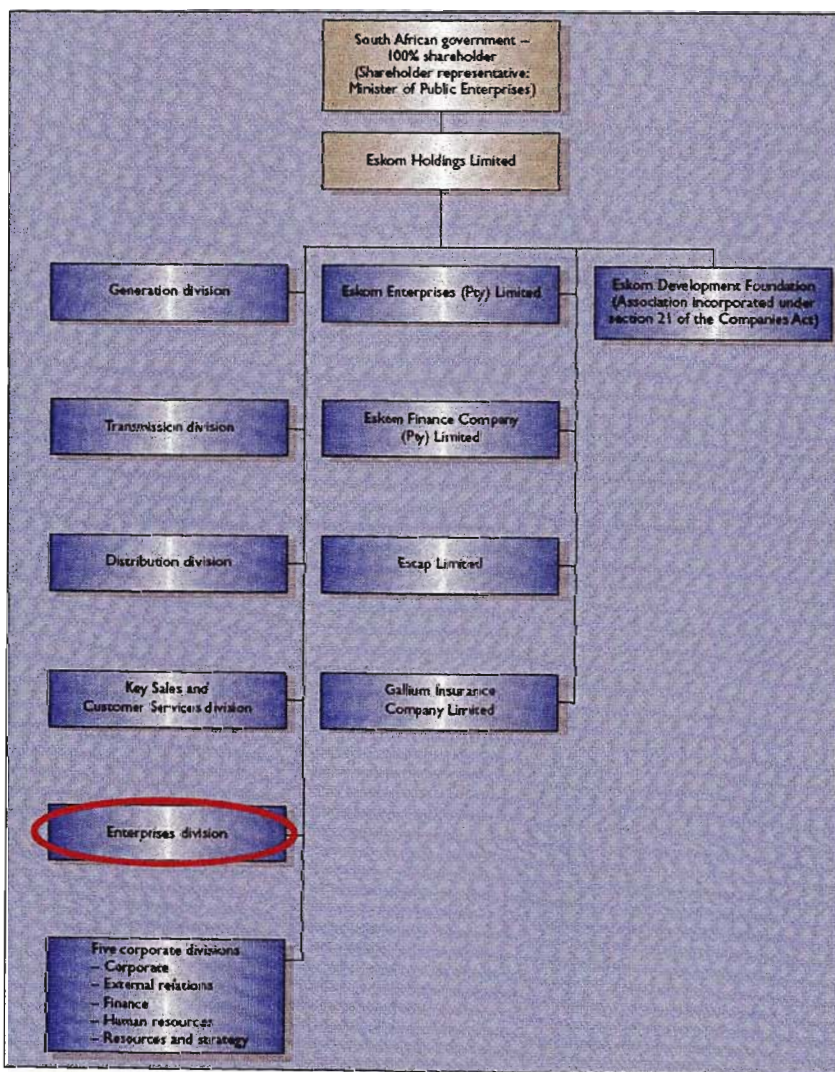


Figure 1 Eskom's Organisational Structure.

2.3 CONTRIBUTORS TO THE SHORTAGE OF ENGINEERING SKILLS

The high number of vacancies¹² for the power generation capacity expansion programme requiring engineering skill demonstrates the shortage of engineering skill in Eskom. There are a number of contributors to the engineering skills shortage for the power generation capacity expansion programme and the following sections describe these contributors to the problem.

The shortage of engineering skills does not apply solely to developing countries such as South Africa but also to the leading economies in the world. Therefore references and comparisons to the leading economies in the world will also be provided.

2.3.1 SOUTH AFRICAN ECONOMY GROWTH & THE SUPPLY OF ENGINEERING SKILL

During the period of the late 1980s through to the early 2000s, large-scale power generation infrastructure was not built and the associated capacity expansion engineering skills wittled away. An example of this skill reduction, was that in the early 1980s, Eskom's centralised Control and Instrumentation section housed approximately 80 engineering staff, whilst in 2002 the figure stood at just 8 engineering staff in the Control and Instrumentation section. This reduction in the number of engineering staff was mainly due to the lack of need for engineering skills at that time which was in turn due to the lack of infrastructure development.

In addition, further review revealed that the number of university engineering graduates per million South African citizens conferred in 1986 was below international levels¹³, as stated by Byleveldt (1990).

However, the growth in the South African economy and the infrastructure required for the staging of a world event, the 2010 FIFA World Cup, has created a peak in the requirement

¹² In February 2006, Mpho Letlape (Eskom Human Resources Managing Director) was quoted as saying that there was a need for 470 engineers based on an R84 billion expansion program at that time, Lünsche 2006. Eskom's 2008 annual report states that 1431 additional people are needed for 2009 and rises to a cumulative total of 2958 additional people in 5 years time.

¹³ In 1986, South Africa's annual production of engineers per million people stood at 42. The **normalised** values (with respect to their economy sizes) are 87 and 193 engineers per million people for Germany and Japan, respectively. A normalised value is used due to economy sizes of Germany (~15:1) and Japan (~30:1) being larger than South Africa in 1986 according to statistics of the International Monetary Fund (2007).

for engineering skills. Lawless (2006) states that the demand for these engineering skills has so far outstripped the supply available in the South African market, with industries estimating a need to increase the engineering resources by 30% to 40%. The South African Department of Education (DoE) stated that four universities have indicated that they are able to increase the number of engineering graduates to assist in meeting the projected need of an additional 1000 engineers per year, Pandor (2008).

With the supply conditions as described by the Engineering Council of South Africa (1998) and the Engineering Council of South Africa (2005) and presented in Figure 2, Eskom has not been exempted from the shortage of engineering skills for its power generation capacity expansion programme. This was noted by Mpho Letlape (Eskom Human Resources Managing Director) who stated a need of a further 470 engineers for the then R84 billion expansion effort as described by Lünsche (2006).

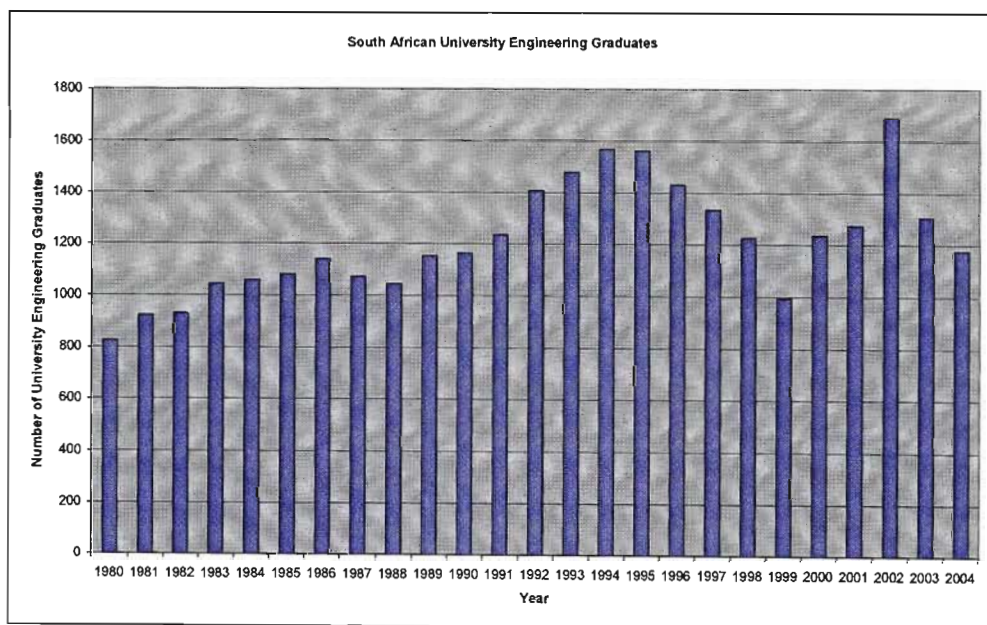


Figure 2 Number of University Engineering Graduates per year in South Africa.

2.3.2 SOUTH AFRICAN EDUCATION SYSTEM

The apartheid system saw the separate schooling of children according to their race in which the children of the minority white population were afforded significantly better primary and secondary schooling resources and facilities than their non-white colleagues.

In addition, the higher education system was also segregated. This segregation policy formed part of a system that sought to define the privileges and roles that the different races were to play (and more so: were not to play) in the South African economy. In essence, the non-white population was relegated to playing support roles to their white counter-parts.

This has exacerbated the short supply of skills (and in particular engineering skills) in South Africa due to the majority of human capital not being adequately utilised in the economy. Byleveldt (1990) identified the shortage of engineering skills as a key constraint that will surface in the building of today's new infrastructure if left unattended. It was suggested by Byleveldt (1990) that the development of engineering skills amongst the Black population must be addressed. However, interventions by Eskom and South Africa¹⁴ thus far were ineffective in alleviating the shortage of engineering skills as demonstrated by the relatively high vacancy rates in the engineering sector.

Added to this, is that engineering skill is the core technical skill for a power generation capacity expansion project, since without the engineering skill, there would be no design work to project manage nor any financial costs to control. An increased demand for the engineering skill coupled to a constrained supply of this same engineering skill will result in an increased cost to these organisations to acquire this skill.

2.3.3 LOSS OF CURRENT ENGINEERING SKILLS

In addition to supply-side problems with respect to engineering skills, South Africa also has the additional problem of not being able to retain all the developed engineering skills. There is an estimate of 300 engineering emigrants from South Africa per year according to a quote by ECSA, Thakali (2008).

Thakali (2008) goes on to state that most of these 300 emigrants are white and that some¹⁵ of the reasons for them leaving South Africa include discontentment with the application of policies to address past imbalances such as Affirmative Action, lack of faith in the

¹⁴ These interventions are described in sections 2.4 and 2.5.

¹⁵ This is not a comprehensive listing of reasons e.g. the level of crime was not listed.

economy and the lure of better prospects in other countries. In support of these reasons for emigration, some labour unions have expressed the view that Affirmative Action causes both black and white engineers to be demoralised in the work place, Solidariteit (2008). This issue is addressed further in section 2.6.7 Skills Retention in South Africa and Globally.

In addition to those engineers leaving the country, it has been stated by the Human Science Research Council (2004) that other sectors such as the financial sector value the engineer's analytical capabilities and therefore make use of engineers in their sectors.

However, the engineering skills problem is not solely a South African issue. Other countries such as Australia and Britain are also facing the shortage of engineering skills as shown in Department of Immigration and Multicultural Affairs (2007) and Global Immigration Services (2006). However, their developed economies allow for better living standards than in South Africa, in certain respects. This allows for these countries to utilise much needed South African – trained engineering skills and subsequently exacerbates the shortage of engineering skills in South Africa.

2.3.4 INEFFICIENT UTILISATION OF ENGINEERING RESOURCES

Eskom is a state-owned enterprise (SOE) that has been organised to provide the infrastructure required primarily to meet the electricity needs of South Africa. However, SOEs exhibit "...unintended consequences of monopol[istic] behaviour, particularly resulting in inefficiencies...", Department of Public Enterprises (2006). Furthermore, the inefficiencies that SOEs exhibit, are well documented in international literature e.g. Officer (1999) states that "...the greater the gap between the owners of an entity and the operators or management, the less efficiently the entity operates."

With Eskom embarking on the power generation capacity expansion programme, the organisational structure which was geared for the operations and maintenance line of business was changed to facilitate the dedication of resources to the power generation capacity expansion programme.

Initially, Enterprises Division's Capital Expansion group was made up of the Capital Expansion Department (CED) and the Project Development Department (PDD), with the former housing both the project management and engineering resources for the execution of projects and the latter housing resources to perform the up-front work to setup the project as described in Eskom (2005a).

In this structure, the engineering resources were perceived in Eskom to be inappropriately sub-ordinated to the project management resources within CED since the project management arm gave less attention to issues pertaining to poor quality (responsibility of engineering) in favour of meeting time and cost constraints (responsibility of project management).

This arrangement was then altered such that the engineering resources were housed in the Enterprises Engineering Department (EED) and were placed on equal footing with the project management resources still housed in CED. This was done to allow for more robust decision making.

However, one of the causes of the inefficiency of SOEs that has been identified by Chiu and Lewis (2006) is that of “redundant labour”. Redundant labour can exist in the form of people that either perform a function(s) that does not contribute to the value chain of an entity or they duplicate effort already performed by other people in the organisation.

In addition, Eskom has made it explicit through its Revised Business Model that there will be “no duplication of skill” within the organisation by documenting the relationship between the department responsible for the implementation of the generation capacity expansion programme and the other divisions, Eskom (2005a).

However, duplication of skill (people performing a duplicate effort) still exists in different parts of the organisation. For example, the engineering resources that were housed in the Generation Technology Department (GTD), a department from the structure prior to the setup of the Enterprises Division, houses resources that could be utilised in EED. This department houses ~20 people with organisational experience mostly greater than 10 years per individual.

2.4 INDUSTRY AND GOVERNMENT PARTNERSHIP TO DEVELOP SKILLS

In 1998 the South African government legislated the Skills Development Act, Republic of South Africa (1998) and one of the purposes of this act is to enable the development of the “skills of the South African workforce... to improve productivity in the workplace and the competitiveness of employers”.

In addition, in February 2006, the Accelerated and Shared Growth Initiative for South Africa (AsgiSA) was launched by government. Further to AsgiSA, the Joint Initiative for Priority Skills Acquisition (JIPSA) is an (initially 3-year) initiative between government, labour and business “... to address scarce and critical skills needed to meet AsgiSA’s objectives” as described in the 2006 AsgiSA annual report, Republic of South Africa (2006a). The following priority skills have been identified in an electronically published document, Republic of South Africa (2006b), for the medium to long term:

1. High-level, world-class **engineering** and planning skills for the transport, communications and **energy industries**.
2. City, urban and regional planning and **engineering skills**.
3. Artisan and technical skills – specifically in **infrastructure development**, housing and **energy**.
4. Management capacity in education and health.
5. Mathematics, Science, Information and Communication Technology (ICT) and language competence in public schooling.

It is noteworthy that, in terms of engineering skill acquisition, points 1 and 3 affect Eskom in the short term whilst 4 and 5 affect Eskom more in the medium to long term.

The Department of Labour (2006) has released a list of scarce and critical skills¹⁶ and this is in alignment with priority skills identified by JIPSA. In addition, a firm survey report by

¹⁶ “In respect of the agreed definition [scarce skills] refers to an absolute or relative demand: current or in future; for skilled; qualified and experienced people to fill particular roles/professions, occupations or specialisations in the labour market. Scarce skills are usually measured in terms of occupation or qualification. Both ‘occupation’ and ‘qualification’ have the merit of being relatively straightforward to measure and readily understood. [W]hile ‘critical’ skills refer to particular capabilities needed within an occupation, for example, general management skills, communication and customer handling skills, team-work skills, communication technology skills.”
Department of Labour (2006).

Pauw *et al* (2006) has confirmed the shortage of engineering skills experienced by South African companies.

In February 2006, Mpho Letlape (Eskom Human Resources Managing Director) was quoted as saying that there was a need for 470 engineers based on an R84 billion expansion program at that time, Lünsche 2006. Further to this, Eskom's 2008 annual report states that 1431 additional people are needed for 2009 and rises to a cumulative total of 2958 additional people in 5 years time.

2.5 ENGINEERING SKILL SHORTAGES IN ESKOM : CURRENT INITIATIVES

This sub-chapter lists and describes the current initiatives used by Eskom to alleviate the shortage of engineering skills in the organisation. The shortage of engineering skills in Eskom can be viewed (simply) as a supply and demand situation, in which the current supply is not adequate to meet the current demand for engineering skill. In addition, the retention of the current engineering skill is inadequate.

The current interventions are classified as retention or supply interventions i.e. their objective is to either reduce the outflow or increase the inflow¹⁷ of engineering skills in Eskom. In addition, the listed interventions are then classified according to the time frame¹⁸ in which the effect of the intervention would impact on the inflow or outflow of engineering skills.

The focus is on efforts to alleviate the engineering skills shortage for the power generation capacity expansion programme in Eskom.

¹⁷ Also the upliftment of the level of skill.

¹⁸ The time frame is split into 3 categories namely short-, medium- and long-term with time durations of less than 1 year, between 1 and 5 years and greater than 5 years, respectively.

2.5.1 SUMMARY OF CURRENT INTERVENTIONS WITHIN ESKOM

Table 2 describes and classifies the current interventions that Eskom has undertaken to alleviate the shortage of skills within the organisation. A description of the intervention is given together with a classification of the intervention in terms of whether it is a supply or retention intervention and the applicable time period in which the intervention is expected to have some effect on the skills shortage problem.

#	Intervention	Description	Retention or Supply	Time Frame
1	Accelerated Recruitment Drives	In addition to print media and radio ¹⁹ being utilised to advertise vacancies, “Career Expos” have been arranged by Eskom to attract new talent into the organisation, Eskom (2007b).	Supply	Short
2	Mentorship & Training Programme	Eskom has put directives in place that cater for the mentorship and development of graduates, Mphelo (2004). In addition, EED is in the process of formulating training programmes for candidate engineers and engineering technologists.	Retention & Supply	Short to Medium
3	Engineering Processes	Although there is a defined process for project management as described by Eskom (2005c), there are no such defined processes for Enterprises Engineering Department (EED) in Eskom. There is currently an effort by EED, led by the author of this dissertation, to define the lower level processes involved in engineering a design for a power station (from conceptual phases through to project completion). A defined engineering process will enable engineers to be trained more easily.	Supply & Retention	Short to Medium

¹⁹ This form of job advertising has not been the norm for Eskom.

#	Intervention	Description	Retention or Supply	Time Frame
4	Improved Systems	In addition to engineering processes being defined, infrastructure in the form of an engineering information management and design tool (Intergraph's SmartPlant [®] Enterprise) is being configured for Eskom's needs. The author of this dissertation forms part of the implementation team.	Supply & Retention	Short to Medium
5	Partnership: Other Companies	Partnerships and service contracts have been established e.g. with engineering (Black & Veatch ²⁰) and project management (Fluor ²¹) consulting companies with the view of developing skills in addition to contracted engineering work for the relevant projects.	Supply & Retention	Short to Medium
6	GARP & TASK	Eskom has initiated a project titled Grading, Assessment and Remuneration Programme (GARP) which includes the implementation of new job grading system named Tuned Assessment of Skills and Knowledge (TASK). The ultimate objective of GARP and TASK is to "[a]chieve a narrow band structure leading to a close-to-market salary comparison in order to attract and retain skills.", Molewa (2007).	Retention & Supply	Medium
7	Bursaries	In the past financial year, 2007, Eskom has provided 5136 bursaries, learnerships and apprenticeships which is up from the previous financial year in which 2163 bursaries, learnerships and apprenticeships were provided, Eskom (2007a).	Supply & Retention	Medium

²⁰ Black & Veatch's international engineering experience is being utilised on Project Bravo (new-build coal-fired power station).

²¹ Fluor's project management skill is being utilised at Grootvlei Power Station: a return to service project.

#	Intervention	Description	Retention or Supply	Time Frame
8	Partnership: Higher Education	Eskom has entered into a number of partnerships with higher education institutions. Examples of this type of partnership are the following: <ul style="list-style-type: none"> • Masters of Commerce (Strategic Project Leadership and Management) degree programme with the University of KwaZulu Natal. • Technology Leadership Programme initially a Diploma (Engineering Business Management) course with the University of Warwick (United Kingdom). • High Voltage Direct Current Center and more recently a Science and Innovation Technology Park with the aim of growing "... innovation in the field of engineering technologies" with the University of KwaZulu-Natal (2007). 	Supply	Medium to Long
9	Partnership: Government	Eskom has supported the AsgiSA and JIPSA initiatives and has actively participated in the process, Mlambo-Ngcuka (2006).	Supply	Medium to Long
10	Eskom University	"In March 2007 Exco approved the concept of an Eskom university as an integrated approach to all Eskom learning activities to ensure that our skills requirements are met.", Eskom (2007a).	Supply	Medium to Long
11	Eskom Expo for Young Scientists	The "Eskom Expos affords South African youth the opportunity to be inspired by science, maths and technology" which are key components to an engineering-related career, Eskom (2007c).	Supply	Long

Table 2 Description and classification of current interventions

Although Eskom has embarked on the initiatives as listed in Table 2, there is still a significant engineering skill shortage in Eskom as per the need that was stated earlier in this dissertation by Lünsche (2006) for a further 470 engineers for the then R84 billion expansion effort.

2.6 ENGINEERING SKILLS SHORTAGE: INTERNATIONAL EXPERIENCE

Although South Africa is experiencing a shortage of engineering skills, other countries are not exempt from this problem (as noted by the references provided in section 2.3.3). Therefore, experience with respect to engineering skills shortage in both developing and developed countries are provided in the following sub-sections. In addition, the interventions that these countries' governments and industrial counterparts have employed to alleviate this shortage of engineering skill, are also described in the following sub-sections.

Firstly, an exploration of the engineering skill migration phenomenon is undertaken. Thereafter, perceptions of engineering skill capability in China (a leading economy in the world) is provided. This is followed up by a description of the role that engineering has to play in developing countries. Subsequently, the interface between industry and academia is discussed. The follow-on topic is the discussion of trends in international engineering curricula .

Furthermore, a discussion of the factors that have contributed to the existing engineering skills shortage in US electric utilities is provided together with suggested interventions to alleviate the problem. Lastly, a look at the representation of women and other under-represented groups, together with the marketing of engineering to attract young people to engineering, is provided.

2.6.1 ENGINEERING SKILL MIGRATION

The Organisation for Economic Co-operation and Development (2006a) suggests to OECD countries that “[a]ny pro-active migration policy is going to involve supplementing ... current entries with selective labour migration, where either employers or the national administration take on the role of identifying appropriate candidates.” These migration policies are intended to alleviate the “...skill shortages in certain occupations...” due to “...ageing populations in OECD countries”, Organisation for Economic Co-operation and Development (2006a).

In addition, it has been identified that there is a need for “...technical skills for wealth creation...”, however, “...[t]he number of people studying engineering at UK universities is decreasing in relation to the overall number of university applicants”, Hawley & Raath

(2002)²². In order to alleviate this problem, both Australia and the United Kingdom allow migration of skilled labour from other countries (in particular, less developed countries) into their economy. It has been reported that currently about 1200 engineers (per year) migrate from various countries to Australia, which is a "...significant proportion of population growth and skills..." in Australia, Trevelyan & Tilli (2003).

As noted in section 2.3.3, South Africa is, through a number of reasons, losing approximately 300 engineers per year to the international community.

Although skill migration has been a positive outcome for the receiving countries (mainly developed), it has had essentially negative outcomes for the sending (mainly less developed) countries. This manifests itself in the less developed countries, such as Pakistan, having to "...pay far more than a developed country would have to pay for the same labour.", Trevelyan & Tilli (2003).

2.6.2 ENGINEERING SKILLS: THE CHINESE FACTOR

South Africa has lagged behind the rest of the world when it comes to the number of engineers produced per million people as noted in section 2.3.1, page 4 (footnote 13). To date, South Africa has not significantly²³ improved on the ~1200 university engineering graduates per year, in 1986, quoted by Byleveldt (1990). The average production rate of university engineering graduates in South Africa from 1994 to 2004 was 1346 per year²⁴ the Engineering Council of South Africa (1998) and the Engineering Council of South Africa (2005), as depicted in Figure 3. In addition to this, note must be taken of the ~300 engineering professionals that are estimated to leave South Africa yearly, Thakali (2008).

In addition, Byleveldt (1990) stated that South Africa had only a 4% enrollment in engineering versus the total university enrollments in the country.

²² In South Africa, the trend is the opposite, since the percentage enrollments in science, engineering and technology has increased from 26% in 2001 to 28.6% in 2005 (in comparison with the total enrollments)..

²³ When comparing the number of university engineering graduates to the general population.

²⁴ This translates to approximately 30 engineering graduates per million citizens per year in South Africa. (= 1346 engineering graduates per year / 45 million citizens)

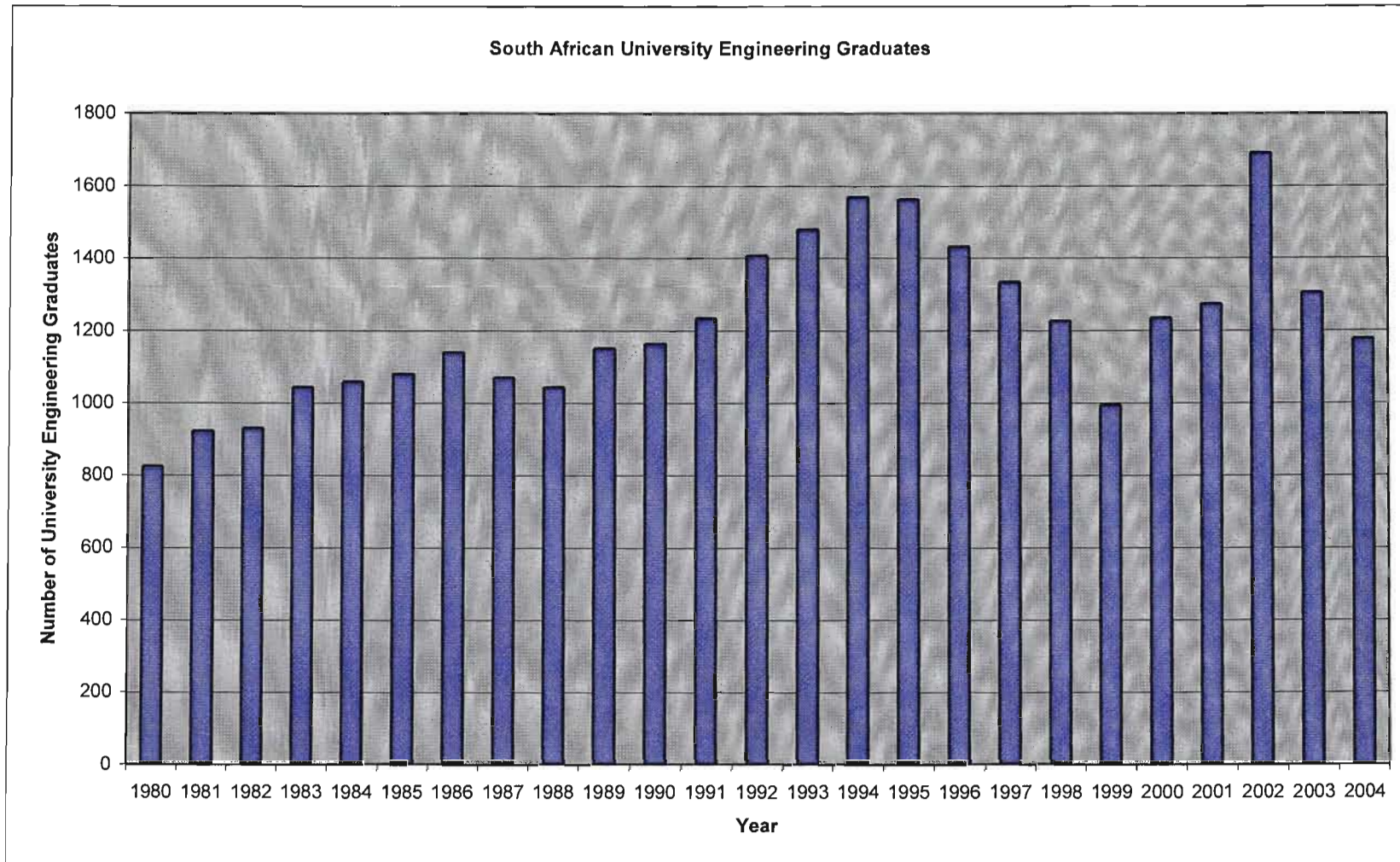


Figure 3 Number of University Engineering Graduates per year in South Africa.

These figures do not present a rosy future for South Africa's technical capability, especially when considering China's equivalent figures which sit at the opposite end of the spectrum. Farrell & Grant (2005) states that China has a 33% engineering enrollment²⁵ of total university enrollments. In addition, Reder (2006) notes that China produces 650 000 engineering graduates per year. Using a population figure of 1.2 billion, this translates to ~542 university engineering graduates per million Chinese citizens per year.

Farrell & Grant (2005) go on to state that China's engineering graduates are more focused towards theory rather than practical and this (supposedly) places them at a disadvantage when working for foreign companies.

2.6.3 THE ROLE OF ENGINEERING IN DEVELOPING COUNTRIES

The Millenium Development Goals (MDGs) and associated targets were set in 2000 and provide a "...reference standard for measuring and tracking improvements in the human condition in developing countries.", Cheong & Jones (2005). Furthermore, it has been stated that "[s]cience and technology offers tools for solving acute problems, as well as for encouraging growth.", Cheong & Jones (2005), and that "...scientists and engineers play a rather critical role..." in "...the innovation process and the implementation (or adoption) process..." of technology, O' Connor & Lunati (1999).

Although OECD countries that make use of training funds and training levies have experienced shortcomings in these systems, Ok & Tergeist (2003) suggest that it helps with spreading the financial burden of training between employers and also helps with the development of under represented groups. In comparison to OECD countries, Brazil faces the added challenge of increasing its economic growth potential by better utilising their (under-represented) female workforce as described by the Organisation for Economic Co-operation and Development (2006b).

2.6.4 THE INDUSTRY/ACADEMIA INTERFACE

The industry and academic interface can be viewed (simply) as a supply and demand scenario, where industrial organisations play the role of customers and the academic institutions play the role of suppliers. The product of this supply and demand scenario is

²⁵ This figure must be compared against South Africa's 30 engineering graduates per million citizens, calculated in footnote 24, to appreciate the difference in number of engineering graduates between the 2 countries.

However this difference must be tempered by the difference in economy sizes of the 2 countries.

that of graduates and more specific to this dissertation: engineering graduates to eventually be utilised in the power generation capacity expansion programme.

Christy & Lima (2005) calls for stronger ties between industry and academic institutions to satisfy the needs of industry, namely "... technically competent entry-level engineers who also have honed their communication skills and possess a deeper understanding of the culture and constraints of the business world." and to satisfy the needs of students of improved "...relevance between their educational experience and future careers."

It has been stated by Robertson & Weihmeir (2005) that the "... requirements for graduate skills and capabilities fall into three categories:

- Technical understanding and competency
- Soft skills such as communication, team-working and business methods
- How all [the above] skills are used and improved "

One study, Keen (1996), found that although industry was satisfied with the technical ability of engineering graduates, "[d]eficiencies in ethics, listening, written and oral communications and responsibility and management were found."

Further support for stronger ties between industry and academia is provided by Ferguson *et al* (2005) which states that a strategy "... for ensuring long-term economic prosperity..." should include "...creation of more effective partnerships between academia, business and industry, and government research institutions that allow for more effective means of technology transfers...". These partnerships will foster more industrially relevant engineering skills.

Ingalsbe & Godbey (2005) suggests that one means of achieving greater collaboration between industry and academia is that a final year undergraduate engineering project "... may also be utilized as a feedback mechanism for faculty to determine competency gaps in the industrial technology curriculum..." and allow for an ammendment to "...classroom instruction in response to rapid changes in demand for particular skills in the local manufacturing sector."

Although not engineering specific, the Organisation for Economic Co-operation and Development (2005) points out that "[m]any adults aged 26 to 45 have been exposed to learning opportunities at work that reinforce the development of their skills..." and that this

may be the reason why "...workers in early to mid career display the best skills among the top end of workforces." The engineering sector in South Africa has a large number of white engineers who are in the end-of-career phase (average age in the region of 60 years) and large number of black entrant engineers, Gabru (2008). There is therefore a gap in terms of engineers in their mid-career.

2.6.5 ENGINEERING CURRICULA

Siller and Gearold (2004) state that engineering curricula must have three components: analysis, synthesis and social skills. These 3 components relate to the core competency of problem solving that an engineer must have, i.e. being able to understand a problem, develop a solution to the problem and then communicate this solution to others. The definition of 'analysis' and 'synthesis' skills is as per the definitions provided in Table 1 on page 4, whilst the 'social' skills refers to components such as communication and team work. Figure 4 provides a breakdown of the three components that an engineering curriculum must have as proposed by Siller and Gearold (2004).

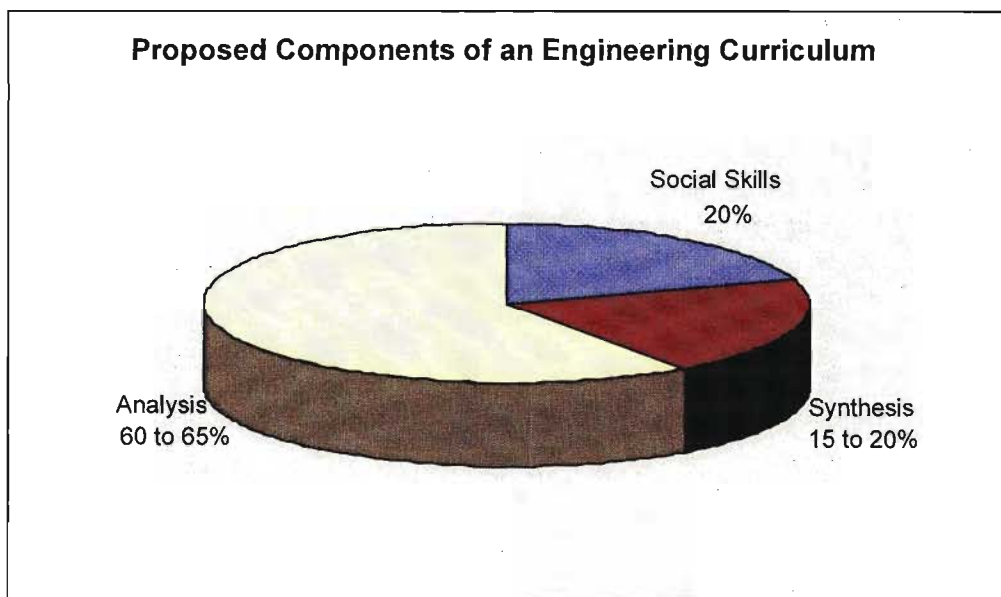


Figure 4 Proposed components of an Engineering Curriculum.

In addition, Crawley (2001) states that "[g]raduating engineers should be able to conceive-design-implement-operate complex value-added engineering systems in a modern team-based environment."

Further to this, Crawley (2001) provides a venn diagram, depicted in Figure 5, that shows the skills that an engineer must possess. Both Figure 4 and Figure 5 show that although the engineer requires analysis and synthesis skills, they will also require social skills.

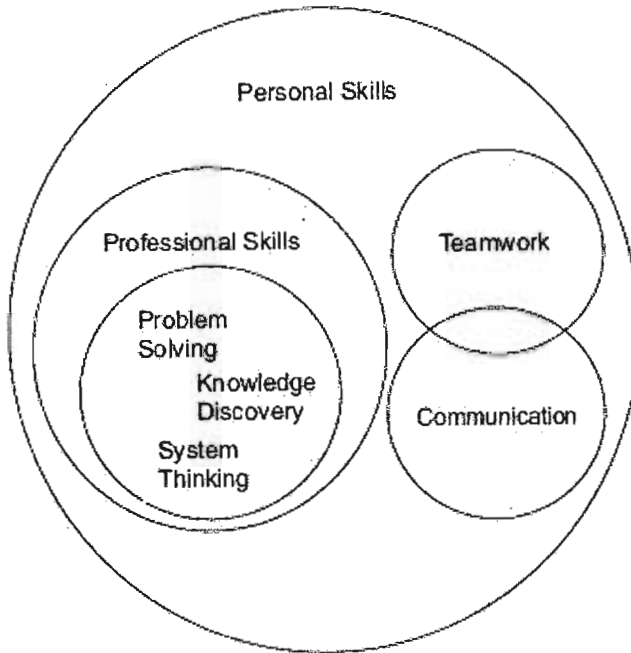


Figure 5 Venn diagram of personal, professional and interpersonal skills.

Patrick & Crebert (2004) states that "...graduates of engineering are perceived to be poor in many skills, particularly at problem solving and oral business communications and interpersonal skills." Although this statement confirms that engineers require more social skills i.e. business communications and interpersonal skills, it also emphasises that engineers also have a flaw in their core professional skill, namely 'problem solving', This flaw is also described by Eidgahy & Eydgahi (1997).

To explain why engineers have this flaw with problem solving, Eidgahy & Eydgahi (1997) state that engineers "...have been trained to solve problems in a fragmented fashion." Engineers are taught to utilise reductionist thinking, namely divide and conquer²⁶. Although reductionist thinking is a necessary component of engineering education, it needs to be supported by a holistic approach i.e. System Thinking as depicted in Figure 5.

²⁶ The problem is broken down into its constituent parts, solved at this partial level, and then re-assembled to form the solution. This approach has its drawbacks if the engineer does not consider the problem as a whole i.e. does not appreciate the enterprise and societal context in which the problem is situated.

The preceding literature suggests that the goal of an engineering curriculum is to include the elements depicted in Figure 4 and Figure 5 which would enable the engineer to understand a problem more fully, subsequently formulate a holistic solution and finally have adequate social skills to communicate and work in team environments to arrive at improved solutions. David Kolb, through his “Experiential Learning Model”, suggests ways based on differing learning styles, of communicating the above elements to engineering students, Oregon State University (2007) and Kolb (1984).

In addition to changes in engineering curriculum, the medium through which the education is delivered is also being challenged. One medium that is attempting to replace or support conventional forms of teaching engineering curriculum is on-line learning. Bourne *et al* (2005) note that engineering has “...subjects that are traditionally the hardest to teach online because of the need for laboratories...” Therefore, it is suggested that blended learning, which is a combination of face-to-face and on-line learning, be utilised for engineering training.

2.6.6 ENGINEERING SKILLS SHORTAGE: FACTORS AFFECTING ELECTRICITY UTILITIES IN THE USA

The electricity system is a complex machine that always has to be maintained in an 'on' state. If this electric system is not maintained in an 'on' state, the impact on people is tremendous since our modern-day society is essentially reliant on electricity. However, Reder (2006) suggests that "short-term financial focus" has resulted in the human resources to design, develop, operate and maintain this system, being whittled away.

The probable causes associated with the lack of technical resources in the electricity industry are summarised in Table 3 (note that all quotes in this table are from Reder (2006))

#	Problem	Description
1	Maturing Technical Workforce	It is estimated that "...20% of the employees will be eligible for retirement within the next five years; in some extreme cases, as many as 40% of the workforce will be eligible for retirement."
2	Poor succession planning	"...succession plans for technical positions were limited..."
3	The Availability of Technical Talent	"The lack of hiring and reduction in employment precipitated a decline in...engineering enrollment[s]..."
4	Increasing Technical Talent Demand	"The technical complexities of integrating new, electronic-based technology into existing infrastructure are growing and require different skills."
5	Non-retirement skills loss	"...portable skills will cause engineers to flee to other industries or cause them to exit from technical disciplines."
6	Unbalanced Workforce Profile	"Recruiting for diverse ethnic and female candidates continues to be a significant challenge." In addition, "...engineering has the lowest percentage of female graduates among all the professions—lower than medicine, law, economics, dentistry, architecture, and pharmacy. Yet, this year, women will make up 50% of the workforce in the United States."

Table 3 Probable causes: Lack of technical resources in the electricity industry

To address this technical resource challenge, Reder (2006) suggests a number of interventions. These interventions are summarised in Table 4 (note that all quotes in this table are from Reder (2006))

#	Interventions	Description
1	“Implement Technology to Reduce Engineering Workload”	“The next evolution of technology deployment could focus on technologies to increase workforce efficiency through standardization, process streamlining, and training simulations.”
2	Outsourcing and Utilising talent trained elsewhere	Consideration should be given to “...outsourcing to third-party firms and utilizing suppliers for technical services.”
3	Technical Workforce Pipelining	<p>a. “...employers can build relationships with universities to convey hiring needs, develop research initiatives, influence curricula, sponsor interns, and continuously hire graduates.”</p> <p>b. “Recognize [that] the labo[u]r pool has changed; ethnic diversity and greater participation by women will provide the long-term solution to power engineering workforce needs.”</p> <p>c. Recognise that “[e]xpertise can be developed with existing employees.”</p>
4	Electricity Industry Image Enhancement	“Remaking the image will attract more power engineering students.” In addition, “[o]pportunities can be created to make role models visible, promoting engineering, especially in middle school when career images are being formed and decisions are made regarding the pursuit of math[ematics] in high school.”

Table 4 Interventions to alleviate technical resource shortage in the electricity industry

In addition, Lave *et al* (2007) argue that “[f]ailing to maintain the skills of today’s workforce by replacing retiring workers with competent substitutes, by training and retraining workers to keep pace with technological change, and by capturing and transferring knowledge more effectively will increase stress to the power systems and could affect the quality of service to consumers.”

Lave *et al* (2007) look at the skills problem along the time domain and considers interventions that should be pursued during the following stages:

1. Pre-recruitment
2. Recruitment
3. Training
4. Retention (of knowledgeable and aging workers)

Firstly, in terms of marketing of engineering to prospective students (i.e. pre-recruitment stage), Lave *et al* (2007) have noted that “[t]he electric utility industry has not enjoyed a glamorous reputation...” and faces “...a demographic challenge²⁷...” and therefore suggests that the electricity industry needs to show that it “...makes a product that is essential to society, that they are environmentally responsible and are working toward sustainability, that the jobs are stimulating and attractive – and that they pay well.”

Subsequently, during the recruitment stage, Lave *et al* (2007) suggest that the electric industry companies “...could even guarantee full-time employment for students who complete the course with satisfactory grades and who did a satisfactory summer internship.”

Thereafter, Lave *et al* (2007) suggest that “...training should be an integral part of employees’ career paths.” Lastly, Lave *et al* (2007) also suggest that “...employees who have retired or are eligible for retirement may be excellent candidates for bridging the transition to a new workforce...” and that by “...using technology and documentation processes, companies can capture and disseminate collective knowledge more easily.”

In essence, the literature surveyed suggests a holistic approach to managing the engineering skills with an electricity industry starting with the pre-recruitment stages all the way through to the retention of existing employees.

²⁷ Due to under-representation of women and minority groups (includes African-Americans) in the US.

2.6.7 SKILLS RETENTION IN SOUTH AFRICA AND GLOBALLY

Ulrich (1998) states that successful companies will be the ones that have the "...capability to find, assimilate, develop, compensate, and retain ... talented individuals." In addition, Ulrich & Smallwood (2004) also state that one of the 11 identified capabilities that a well-managed company must have, is to be "...good at attracting, motivating, and retaining competent and committed people."

However, Bussin & Spavins (2007) suggest that "...[o]ne of the characteristics of the knowledge economy is the high level of mobility of knowledge workers." Engineering personnel form part of these knowledge workers and are by no means exempt from this mobility issue.

In addition, the skills shortage challenge and associated use of retention strategies to mitigate against this skills shortage is not a South African phenomenon alone, Horwitz (2007). Horwitz (2007) suggests that in order for companies to retain these knowledge workers, the following 6 identified needs of these knowledge workers need to be understood:

1. Competitive market-based and flexible pay and employment practices.
2. Intrinsic work factors need to be addressed e.g. autonomy and job satisfaction, planning and control over work, recognition and reward.
3. Opportunity to do challenging work that is exciting and stimulating.
4. Growth and skills development.
5. Social networks and peer group relations.
6. Create and sustain organisational context i.e. "...actively build and sustain a sense of personal and organisational mission."

Horwitz (2007) goes on to state that in respect of "...staff turnover, most South African workers quit their jobs because of a lack of career advancement and effective utilization of their knowledge and skills."

In addition, Ramlall (2003) identified that the following were the top 3 reasons as to why employees chose to change their jobs:

1. Salary not being market related
2. Lack of challenge and opportunity
3. Lack of career advancement opportunities

Further to this, De Conje *et al* (2004) define motivation (in a broad sense) as "...the reason people want to work." This broad definition of motivation caters for the 6 factors described above by Horwitz (2007). The conclusion that can be drawn from this is that employee motivation and the ability of companies to retain employees are tightly coupled.

In South Africa, certain policies such as the Employment Equity Act and the associated Affirmative Action policy are believed to be contributing to the unintended consequences of instability in the employment market which results in the phenomenon known as the "Revolving-door Syndrome"²⁸. Motileng (2004) refers to literature which both support and contest the proposition that Affirmative Action is harming those individuals that it intends to provide benefit to. The study performed by Motileng (2004) summarises his findings on the experiences of affirmed employees and states that the application of Affirmative Action "...policies increase job satisfaction and organisational commitment among beneficiaries."

In addition, Cilliers (2006) state that in practice "...the experience is that if the organisation cannot 'get the cultures right', it results in the cost of the so-called 'revolving door syndrome' " and he attributes this "...to ongoing harassment and a lack of progressive development opportunities...". However, due to the transformation requirements of the Employment Equity Act and the scarcity of these affirmative action candidates (especially in engineering) there is an unintended consequence being that these candidates are presented with ever increasing remuneration packages for work they may not have the competency to perform.

The author of this dissertation notes in summary, that although there is positive intention in these policies, the actual implementation in each company determines its relative success in achieving the policies' objectives.

²⁸ The "...phrase refers to the ease with which companies are able to recruit new Affirmative Action candidates and the equal ease with which these recruits can feel frustrated, disillusioned and eventually leave the company.", Motileng (2004).

2.6.8 WOMEN AND OTHER UNDER-REPRESENTED GROUPS IN ENGINEERING

Women and ethnic minority groups²⁹ are under-represented in the engineering profession in the USA, Reder (2006). Although great strides have been taken in the USA to increase the number of women in engineering professions from 0.8% in 1971 to the 20.1% in 2004, the engineering profession still lags behind other professions who have achieved approximate gender parity, Morsi (2005) and Cordova-Wentling & Camacho (2006). During the past decade this figure has hovered around the 20% mark for women in engineering, Islam (2006) and Reder (2006).

One explanation for this trend is that offered by Aultman-Hall & Holmen (2006), which states that “[w]omen and minorities do not see engineering as an opportunity for themselves because the “face” of engineering does not look like them and, furthermore, they have little first-hand knowledge of what the engineering profession is all about.” Aultman-Hall & Holmen (2006) go on to suggest that “...diverse leaders are needed as role models to attract girls, young women and under-represented men³⁰ to engineering.” In addition, advice to the engineering profession and engineering associations was that they should demand (of academics) diversity in engineering.

Another explanation (not mutually exclusive to the prior explanation) is also offered by Seat (1998), in which it is suggested that women engineers “...become dissatisfied in their careers ... because of social interactions and interpretations of workplace dynamics...” and require coaching to “...be taught to acknowledge their ability and skill...[and] to have confidence in their ability to solve problems.” This explanation is corroborated by the statement in Zastavker *et al* (2006) that “...men and women differed in perceptions of self-competency. Men reported being more competent than their peers, whereas women reported being less competent...”.

Jahan *et al* (1998) suggest that “[t]he solution for better participation of women in engineering is a change in the society at large...” where the “...notion that girls are not strong in analytical, problem-solving skills is also rampant in most societies...” should be dismissed. It is also suggested that “[e]xposure to engineering careers and dismissing myths about physical hardship and strenuous labo[u]r are also extremely important...” for improving the intake of women into engineering.

²⁹ This includes the designated group: African-American.

³⁰ If the percentage representation in a profession is less than the actual demographics of the country, this is defined as under-representation.

Reder (2006) included a table from a US context that provides "...a summary of boys' and girls' participation in math[ematics] and related studies from junior high school through college graduation." The table's data³¹ is reproduced here in Table 5 with added calculations by the author of this dissertation.

Phase	A	B	C	D	E	F	
Phase Title	Starting Study Group	7th Grade	12th Grade	College Entry	College Graduation	College Doctorates	
Phase Descriptor	Starting Study Group	Understand math well enough to take advanced high school math classes	Take enough math for a quantitative college major	Enter college with plans to major in science	Number emerging from college with baccalaureate degree	Number emerging with Ph.D. in quantitative field degree	
1	Male	2000	1000	280	140	45	5
2	Female	2000	1000	220	45	20	1
3	% Gender Difference in each phase	0%	0%	21%	68%	56%	80%
4	% Male proceeding to next phase	50%	28%	50%	32%	11%	Not Applicable
5	% Female proceeding to next phase	50%	22%	20%	44%	5%	Not Applicable
6	% Gender Difference proceeding to next phase	0%	6%	30%	-12%	6%	Not Applicable

Table 5 Gender differences in mathematics and science participation

Of significance are the following two points that the author of this dissertation observed:

1. The major difference in participation levels between the sexes is in the entry to college, since 1 out of 5 (~ = 45 of out 220) females at 12th Grade will make the decision to enter college with plans to major in science versus 1 out of 2 males (=140 out of 280). The author of this dissertation suggests that this is the major bottleneck in the quest to improve the number of female engineers.
2. On a percentage basis comparison, more females graduate from college with an engineering degree (44%) than males (32%). This emphasises the benefit that could be realised if more women pursued careers in engineering.

To compare, in 2004, 19% of the engineering graduates were female in South Africa, Engineering Council of South Africa (2005). This figure was preceded by lower levels of female engineering graduates in the years prior to 2004 (up from 11% in 1998), as depicted in Figure 6 provided by the Engineering Council of South Africa (2005). The significance

³¹ Only rows 1 and 2 form part of the data provided by Reder WK (2006), the rest of the data rows form part of the author's calculations utilising the row 1 and 2 data.

of the trend depicted in Figure 6 is that although there is a positive trend from 1998 to 2004, the female population is still under-represented in the engineering field.

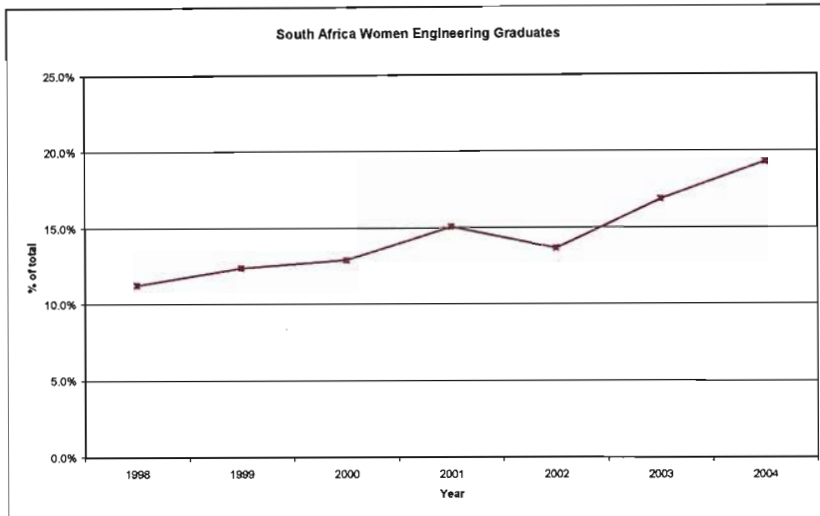


Figure 6 South African Women Engineering Graduates.

In addition, the number of black male engineering graduates in South Africa in 2004 as described by Engineering Council of South Africa (2005) was ~42% of the total male engineering graduates. The trend of black male graduates from 1998 to 2004 is shown in Figure 7 (provided by Engineering Council of South Africa (2005)) and when compared to the demographic fraction of ~88%, the significance of the under-representation of black males in the engineering field is evident.

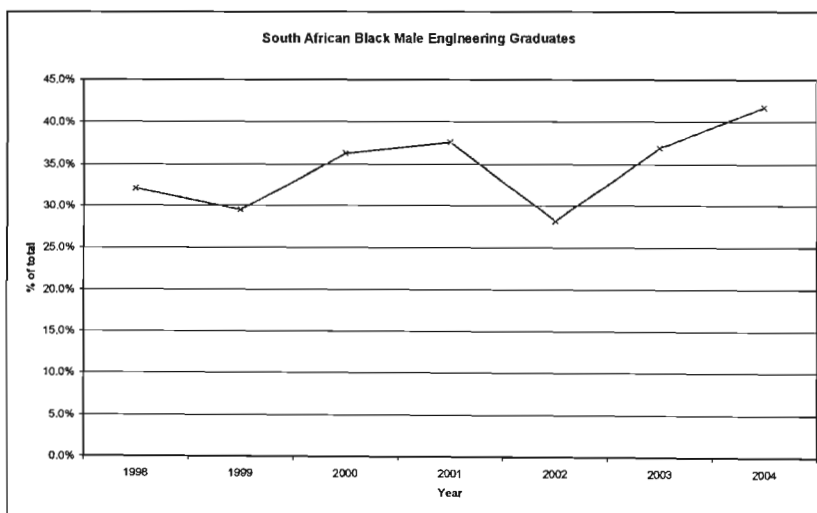


Figure 7 South African Black Male Engineering Graduates.

As a comparison, the ICT sector (another skills shortage sector in South Africa) has implemented a number of government and private enterprise initiatives to increase the

participation of females in the ICT sector. In 2002 the participation of females was ~20%, Vukanikids (2005). However, with the success of these initiatives that range all the way from early school development through to tertiary education support, there is now a ~50% representation of females in the ICT student population, Smith *et al* (2006).

In fact, it was reported in a study of women in ICT published in 2008 that South Africa has the highest percentage of female graduates in the science and technology field when compared to other countries and regions in the world, Reding (2008).

2.6.9 MARKETING OF ENGINEERING

It has been noted by Reder (2006) that engineering enrollments in the USA are on the decline. This decline could be attributed (in part) to "...decreased interest in advanced math[ematics] and science coursework ..." in schools and the image of engineering having "...suffered in media presentations of "geeks" and "nerds" confined to cubicles, disrespected by management and members of the opposite sex...", Summers & McCulley (2006). It has been suggested by Summers & McCulley (2006) that "...engineering must become more competitive in marketing an improved image."

Blenkinsop *et al* (2006) note that family members are "particularly influential" in a young person's (14 to 16 year olds) decision making process. In addition, both mathematics and science were perceived to be very important for their careers and they enjoyed science more than mathematics³². This latter statement augers well for university enrollments in engineering, however, the low number of engineering enrollments in the USA persist, Reder (2006).

In comparison, Figure 8 assembled with data from the DoE of South Africa shows that there was an increase in enrollment to Science, Engineering and Technology tertiary programmes of approximately 3% over a 4-year period from 2001 to 2005. However, this increase has not alleviated the under-representation of women and black males in the South African engineering profession.

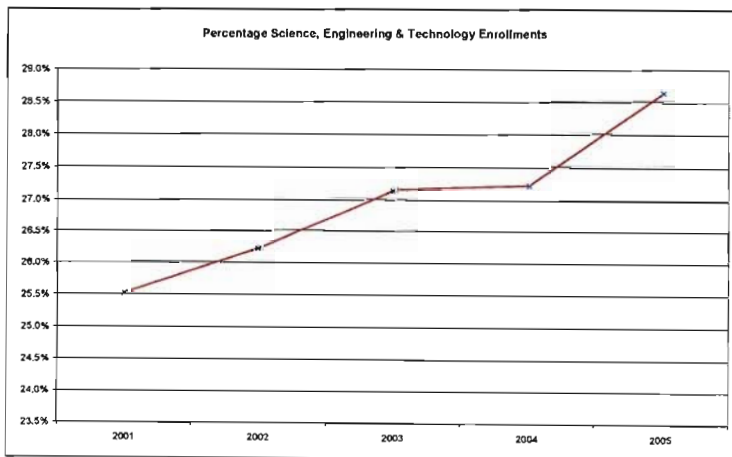


Figure 8 Percentage Science, Engineering & Technology enrollments in Higher Education institutions in South Africa.

In terms of career information, Tyers & Sinclair (2005) state that advice or guidance received by older age groups from 20 years to 50+ in the UK shows that the most influential groups (excluding formal career guidance initiatives) are:

1. Adviser at a school/college/other education centre
2. Employer
3. Family member/friend

The author of this dissertation notes that family members/friends are the common denominator from ages 14 years upwards when it comes to career decision making .

Blenkinsop *et al* (2006) also points out that the majority of young people in the UK do not perceive mathematics and science as having gender biases. Furthermore, as part of a training camp to create interest and change perceptions on engineering amongst girls, Pyke *et al* (2006) took a marketing approach to setting up the camp in the USA with the following four message themes:

1. Engineers help the world.
2. Engineers think creatively.
3. Engineers enjoy working with others.
4. Engineers earn a good living.

The usage of these message themes could assist (by improving the image of engineering) with rectifying the under-representation of women and black males in the engineering profession.

³² Enjoyability of mathematics was more evenly distributed i.e. an approximately even number enjoyed and disliked it as a subject at school.

CHAPTER 3 : RESEARCH MODEL & METHODOLOGY

3.1 RESEARCH MODEL

The research question for this dissertation took the following form:

What is the extent of the engineering skills shortage in Eskom (that is being experienced in the power generation capacity expansion programme) and what is the impact of current and proposed interventions to alleviate this engineering skills shortage ?

The focus for this research was to understand the engineering skills shortage problem in Eskom, *especially as it relates to Eskom's power generation capacity expansion programme*. In addition to the above primary research question, the following secondary research questions were posed:

1. What is the existing engineering skills base in Eskom?
2. What is the engineering skills shortage (quantify) in Eskom?
3. What interventions are currently being pursued by Eskom to alleviate this problem? What is the impact of these interventions on the situation?
4. What further interventions can Eskom pursue to alleviate this problem? What is their likely impact on the situation?
5. What are the most effective interventions that Eskom can pursue?

It is expected that by answering the first three secondary questions, that the engineering skills shortage in Eskom will be quantified and an appreciation of the impact of current interventions will be gained. Furthermore, in order to answer the fourth and fifth secondary question, the methodology as provided in section 3.2 was followed.

3.2 METHODOLOGY

To answer the questions posed in section 3.1, the methodology depicted in Figure 9 was followed.

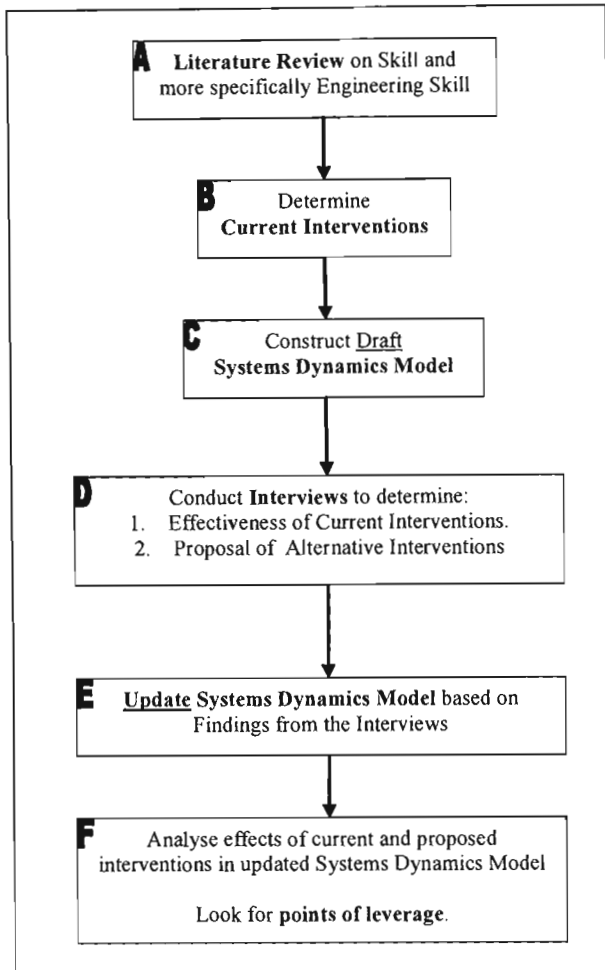


Figure 9 Methodology utilised to understand the problem and to determine interventions

In order to provide the author of this dissertation with a better understanding of the engineering skills shortage situation, the method included a literature review, depicted as phase A of Figure 9. This was followed by a review of the initiatives that Eskom had already undertaken to address the engineering skills shortage issue, depicted as phase B of Figure 9.

Thereafter, systems dynamics modelling together with interviews were chosen as the means to gain a more complete understanding of the situation, depicted as phases C through to F of Figure 9. The justification for the use of systems dynamics modelling is provided in section 3.2.1 and the subsequent section 3.2.2, provides a list and associated rationale for

the selection of the interviewees. In addition, Table 6 provides a more comprehensive narrative of the six phases (A to F) of the sequence chart in Figure 9.

#	Phase	Description of Methodology Phase
A	Literature Review	The results of this phase is provided in Chapter 2. It is significant to note that while other engineering shortages are experienced in Eskom, the focus of this research is the engineering skills shortage in Eskom's capital expansion programme carried out by Enterprises Division.
B	Current Interventions	A listing and description of current interventions to alleviate skill shortages have been provided in section 2.5.1. It is important to note that although there are a number of interventions that Eskom has undertaken to relieve the shortage of skills, these have so far been insufficient to rectify the situation.
C	Draft Systems Dynamics Models	A draft systems dynamics model was developed. The reason for the use of systems dynamics modelling as a tool in this research, is provided in section 3.2.1.
D	Interviews	Interviews were conducted to achieve the following: <ol style="list-style-type: none"> 1. Determine the perceived effectiveness of current interventions. 2. Gather proposals for alternative interventions that could lead to an improvement. 3. Gain a better understanding of the problem by listening to the views of the participants who represent the different stakeholders.
E	Updated Systems Dynamics Model	The draft systems dynamics model developed in phase C, was embellished and altered to accommodate the views of the interviewees.
F	Points of Leverage	The effects of current and proposed interventions were analysed by utilising the updated systems dynamics model as a "what if" scenario tester. Behaviour over time graphs were examined and the manipulation of variables to see effects over time were carried out. In addition, the author also looked for unutilised or under-utilised points of leverage.

Table 6 Narrative of methodology presented in Figure 9

3.2.1 JUSTIFICATION OF SYSTEMS DYNAMICS MODELLING AS A RESEARCH TOOL

Systems Dynamics Modelling is located within the field of Systems Thinking. The essence of Systems Thinking is to understand the multiple perspectives regarding a problem prior to solving the problem, since the perspective we have will affect "...the way [we] approach situations or undertake specific tasks", Lane A (2000).

Furthermore, the complexity of a problem is gauged by its combinatorial and dynamic complexity. Most people tend to think of complexity in terms of combinatorial complexity i.e. the "...number of components in a system or the number of possibilities one must consider...", Sterman (2001). However, the problematic type of complexity (in terms of understanding and subsequently seeking a solution) is dynamic complexity i.e. the complexity that arises out of the relationships between the entities in a system. These relationships also possess a time dimension.

3.2.1.1 MENTAL MODELS: THE DRAW-BACKS

Without the use of system dynamics tools, people seeking to understand issues or problems that they face, will have to rely solely on their mental models³³ to understand these issues or problems. However, our mental models have a number of limitations such as the biases that we hold in our perspectives and the imprecise boundaries that these mental models have.

In addition, the mental models in most cases cannot represent all the significant interrelationships between the entities in the system under consideration, due to the complexity of these interrelationships. The solutions that are then derived from the understanding gained from these mental models are at best short term fixes and more often than not, they lead to unintended emergent consequences, Sterman (2001).

Systems dynamics with the exploration of a system's behaviour over time can overcome the "static, narrow and reductionist" view that mental models offer, Sterman (2001). The initial outcome of the use of systems dynamics tools is that the mental models of the modeller and the other participants become explicit to each other by being able to represent³⁴ their mental models in the systems dynamics model. This allows for the

³³ A perspective held by a person within their own mind i.e. they have not made their perspective explicit on paper.

³⁴ In diagrammatic form.

systems dynamic model to be challenged and improved by taking in the perspectives of all the participants. This subsequently provides a broader and richer picture of the system.

3.2.1.2

SYSTEMS DYNAMICS: DEALING WITH DYNAMIC COMPLEXITY

Systems dynamics modelling can be used to build "...quantitative and qualitative models of complex problem situations..." in a real world context and then gain understanding of the system by studying "...the relationship between the behaviour of the system over time and its underlying structure and strategies/policies/decision rules...", Caulfield & Maj (2002).

System dynamics modelling allows for the use of soft variables as well as the conventional hard variables, Caulfield & Maj (2002). Examples of variables that can be measured directly i.e. hard variables are number of students, number of graduates and number of engineering employees, whilst examples of variables that are difficult to measure i.e. soft variables are employee motivation, anger and confidence. This allows the systems dynamics model to provide the modeller with a more informed concept of the problem space being dealt with.

In addition to the added understanding that systems dynamics models offer, there are a number reasons for using a systems dynamics model in addition to the mental models that we hold and these are given as, Cavanna & Maani (2001):

1. More information can be contained in a systems dynamics model than a mental model.
2. "Causal relationships and assumptions can be formulated clearly and unambiguously", Cavanna & Maani (2001).
3. Assumptions, different structures and policies can be easily altered for alternative model experiments.
4. Sensitive parameters can be easily identified through repeated experiments.
5. Uncertainties and errors can be incorporated into the model more explicitly.
6. The systems dynamic models also allow for easier communication of mental models held by the participants.
7. Both linear and non-linear relationships as well as physical and information delays are readily incorporated into a systems dynamic model.

Therefore, the "open box" approach offered by systems dynamics modelling is the key ingredient to allowing the author of this dissertation to gain an improved understanding of the engineering skills shortage issue. In addition, the allowance for qualitative models to be

built is key to this research since not all the variables that need to be modelled are quantitative.

3.2.1.3 THE USE OF A DRAFT SYSTEMS DYNAMICS MODEL

With the use of systems dynamics modelling, individual learning by the author of this dissertation is aided through better understanding of the issue at hand. This is achieved by making explicit the assumptions within the mental models held by the author of this dissertation. The author of this dissertation, after having made his assumptions explicit by means of stocks and flows in the draft systems dynamics model, is afforded the opportunity to challenge the identified assumptions.

From the errors and omissions identified in the model, the author of this dissertation can then rectify and update the model to improve his understanding of the issue at hand.

3.2.1.4 THE USE OF AN UPDATED SYSTEMS DYNAMICS MODEL

The use of systems dynamics models makes the mental models of the author of this dissertation explicit. Therefore, the interviewees are able to challenge the assumptions in the model. This allows for further learning than was possible if the author of this dissertation maintained only mental models of the issue at hand. In essence (in terms of group learning), the system dynamics model provides a better means of communicating the mental model that the author of this dissertation holds, to enable improved group understanding of the issue at hand.

In addition to an improved understanding of the problem, advantages of system dynamics modelling have been provided in section 3.2.1.2. Furthermore, the two advantages that are of importance to this research are the following:

1. Assumptions, different structures and policies can be easily altered for alternative model experiments.
2. Sensitive parameters can be easily identified through repeated experiments.

3.2.2 INTERVIEWEE SELECTION

In order to identify the interviewees for this research study, the author chose to firstly determine who the stakeholders are within Eskom. These stakeholders are represented in the systems map of Figure 10.

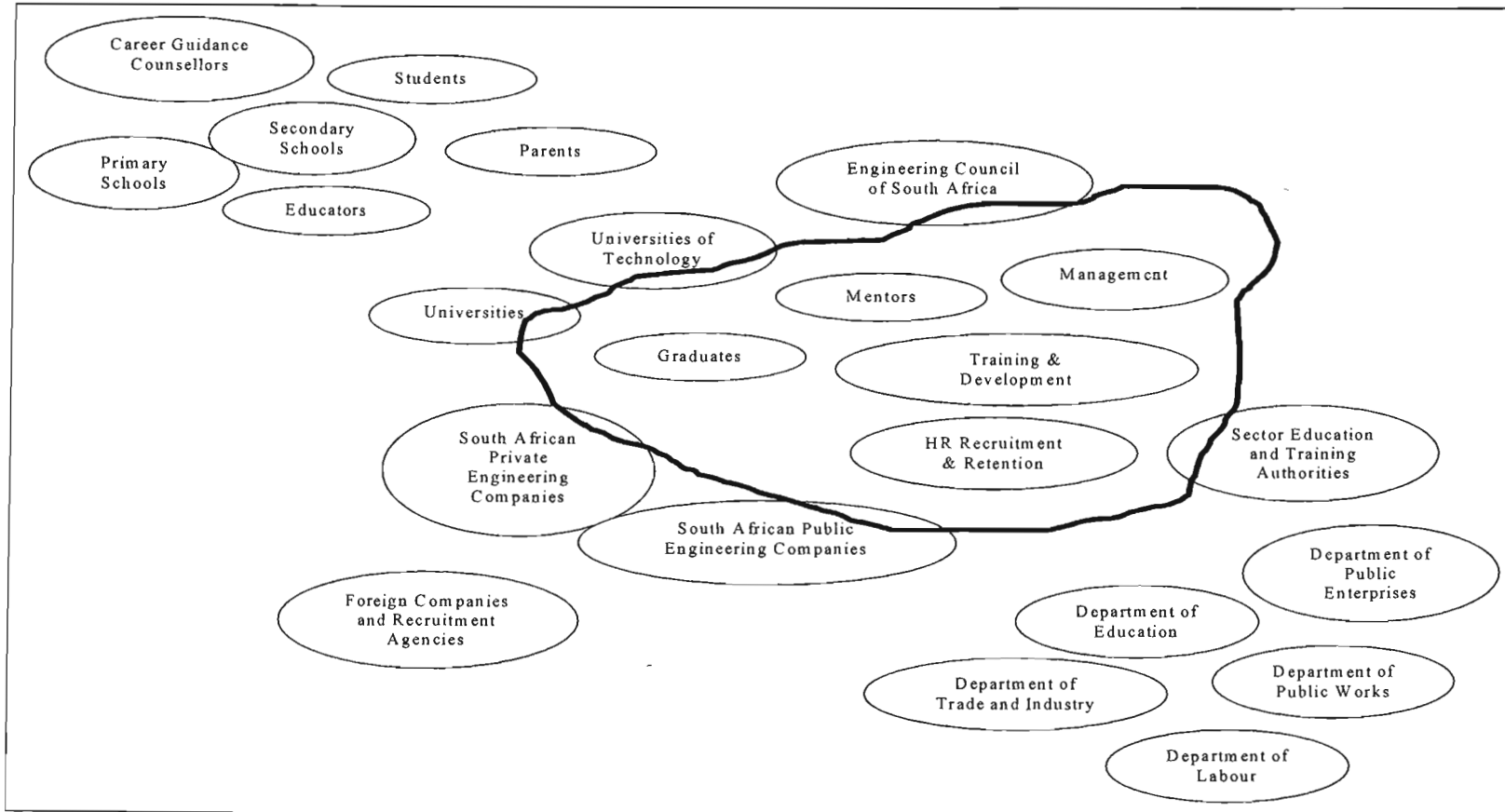


Figure 10 Systems Map of Engineering Skills in Eskom

Furthermore the stakeholders within Eskom are contained within the boundary drawn on the systems map provided in Figure 10:

- Graduates
- Mentors
- Management
- Training & Development
- HR Recruitment and Retention

In order to get a representative sample of the above stakeholders and their views in which to embellish the systems dynamics model, interviewees were selected as per Table 7.

#	Role	Interviewee's Name ³⁵
1	Former Head of Enterprises Engineering Department (EED) and currently General Manager (Nuclear Programme)	Clive Le Roux
2	Human Resources Manager (Shared Services: at time of interview)	Elsie Pule
3	Leadership and Professional Development Manager (located within the Human Resources department)	John Gosling
4	EED Discipline Engineering Manager	Dieter Huppe
5	Senior Engineering Staff (Chief & Senior Engineers, Senior Engineering Technologists, Senior Technicians)	Johannes van Tonder & Eugene Motsoatsoe
6	Engineers and Engineering Technologists	Samantha Kali & Zubair Moola
7	Graduates in Training	Christoph Kohlmeier

Table 7 List of Interviewees

Questions that were posed to each of these groups of people are provided in Appendix 1: List of Questions per Interviewee.

The aim of gathering the various perspectives via the research interviews was to gain a better understanding of the problem and then to represent this understanding in an updated systems dynamics model. The eventual aim is then to utilise this updated systems dynamics model to identify points of leverage in the system to alleviate the shortage of engineering skills in Eskom for its power generation capacity expansion programme.

CHAPTER 4 : DATA SUMMARY AND ANALYSIS

After reviewing the literature that was presented as a summary in Chapter 2, the author of this dissertation then prepared a draft systems dynamics model using the process summarised in Table 8.

#	Activity	Description of Activity
A	Draw Rich Picture	A rich picture that represented the author's view of the engineering shortage in Eskom, especially as it relates to the capacity expansion projects, was drawn up.
B	Develop Systems Map	A systems map was developed to represent the different entities in the shortage of engineering skill issue and to assist in bounding the issue.
C	Develop Influence Diagram	Utilising the Systems Map, an influence diagram was developed to expose the author's understanding of the interactions between the different entities.
D	Produce Multiple Cause diagram	A multiple cause diagram reflecting the cause and effect pairs, positive and negative feedback causal loops were identified.
E	Assemble Draft Systems Dynamics Model	Finally, a draft systems dynamics model was constructed utilising the information provided by the previous 4 steps in this table.

Table 8 Narrative of the methodology utilised to arrive at a draft System Dynamics Model

The literature review, in terms of current interventions that Eskom is pursuing to alleviate the shortage of engineering skills, was used as a basis to determine the interviewees' perspective on the impact of current interventions. In addition, this list of current interventions, presented in section 2.5.1: Table 4, was extrapolated to include any interventions that the interviewees mentioned that was not originally identified by the author of this dissertation. Furthermore, suggestions of additional interventions that the interviewees thought would assist in the alleviation of engineering skills shortage in Eskom for the capacity expansion projects was elicited.

³⁵ Consent has been provided by the interviewee to not remain anonymous.

Finally, a updated system dynamics model together with an analysis of the effects of changes to the system and associated points of leverage was documented.

4.1 DRAFT SYSTEMS DYNAMICS MODEL DEVELOPMENT

4.1.1 RICH PICTURE

The rich picture depicted in Figure 11 was developed by the author of this dissertation as part of a term paper, Moodley (2006a).

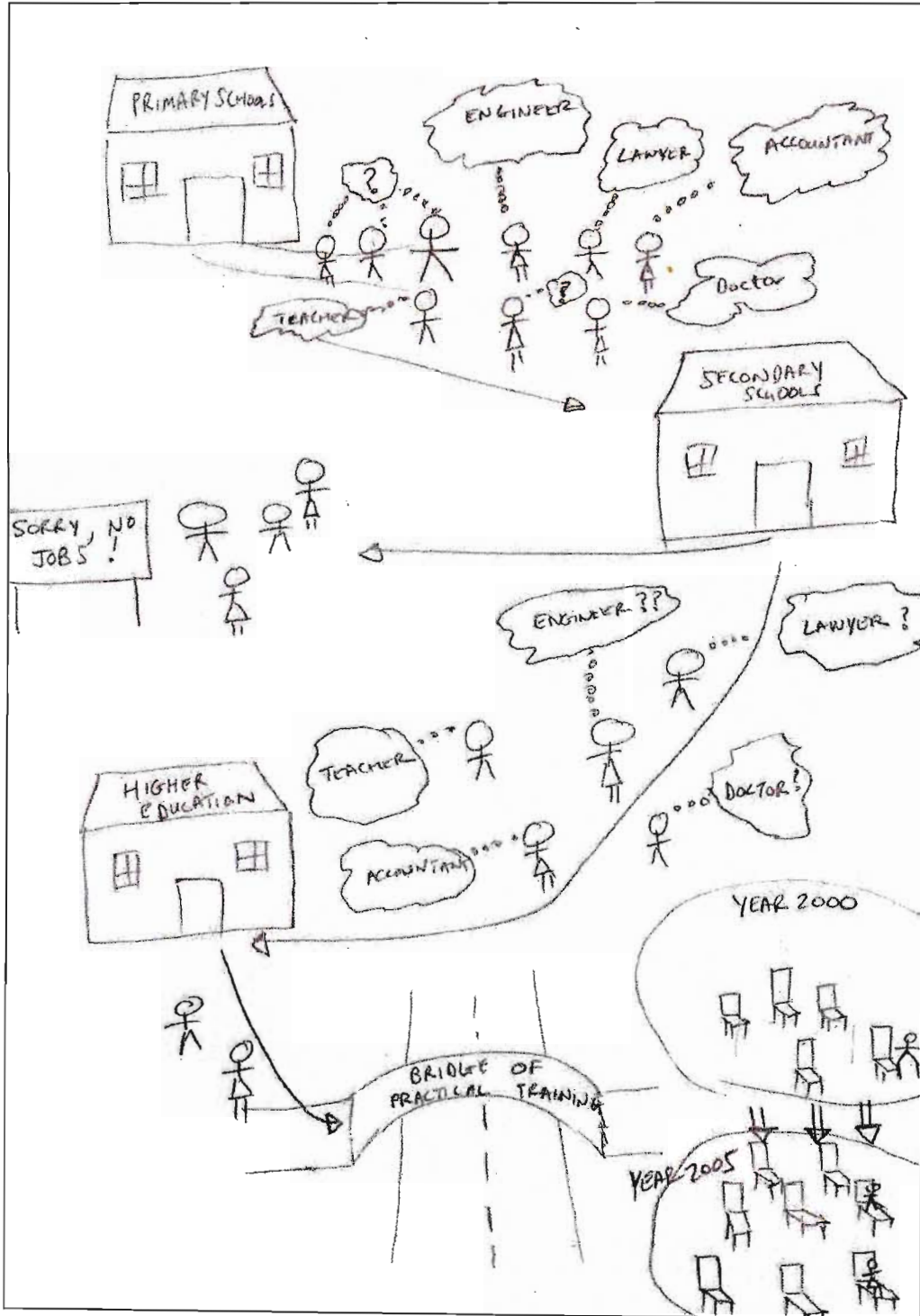


Figure 11 Rich picture of the ability of the engineering sector to attract students

From the top left section of the rich picture given in Figure 11, the author noted that there are a number of students that complete primary school education without having established what their interests are. The author of this dissertation classifies these students as those that have not been exposed to the benefits of the engineering sector, as discussed in section 2.6.8: Women and Other Under-Represented Groups in Engineering as well as section 2.6.9: Marketing of Engineering.

After completing secondary school education, there are a number of students who do not proceed onto higher education and are faced with the prospect of not finding a job in certain sectors, Braehmer *et al* (2000). The author of this dissertation sees some of these students as those that have not had exposure to the engineering sector, as discussed in section 2.6.8: Women and Other Under-Represented Groups in Engineering as well as section 2.6.9: Marketing of Engineering.

Some of the high school graduates, although moving on to higher education institutions, are still not sure of their careers. Apart from family members and employers, advice from guidance counsellors are found to be among the top influencers on youth career choices as described in section 2.6.9: Marketing of Engineering.

Once the engineering graduates from higher education institutions have completed their studies and are ready to enter the work place, they have to go through a practical training period since they have not been sufficiently exposed to the work environment. The author sees this as a gap between the expectations of the engineering firms and the graduates that the universities are producing, as discussed in section 2.6.4: The Industry/Academia Interface.

The last discussion point in the rich picture is that the number of engineering positions in companies is increasing at a faster rate than the number of engineering and engineering technologist graduates being produced (depicted as an increase in the number of empty seats as shown in the bottom right corner of Figure 11). This can be attributed to the number of contributors as identified in section 2.3.

Note that the loss of staff to international companies was not shown on this rich picture. At the time that the term paper was being written, the author had only considered the engineering skills shortage as a simplified supply and demand scenario i.e. the attrition of skill was not addressed. This omission represented a significant flaw in the author's mental model of the issue.

In addition, the rich picture also exposes the author's bias towards identifying the problem as more of a supply issue and less of a demand issue, by allocating more space to the supply side of the rich picture³⁶.

Both of these flaws are addressed in the draft systems dynamics model presented in section 4.1.5.

³⁶ Only the bottom right section of the rich picture depicts the issue as a demand problem.

4.1.2 SYSTEMS MAP

The systems map of the engineering skills in Eskom that was provided in Figure 10 is repeated here in Figure 12 for ease of reference. Those entities within the boundary depicted in Figure 12 are the key stakeholders within Eskom.

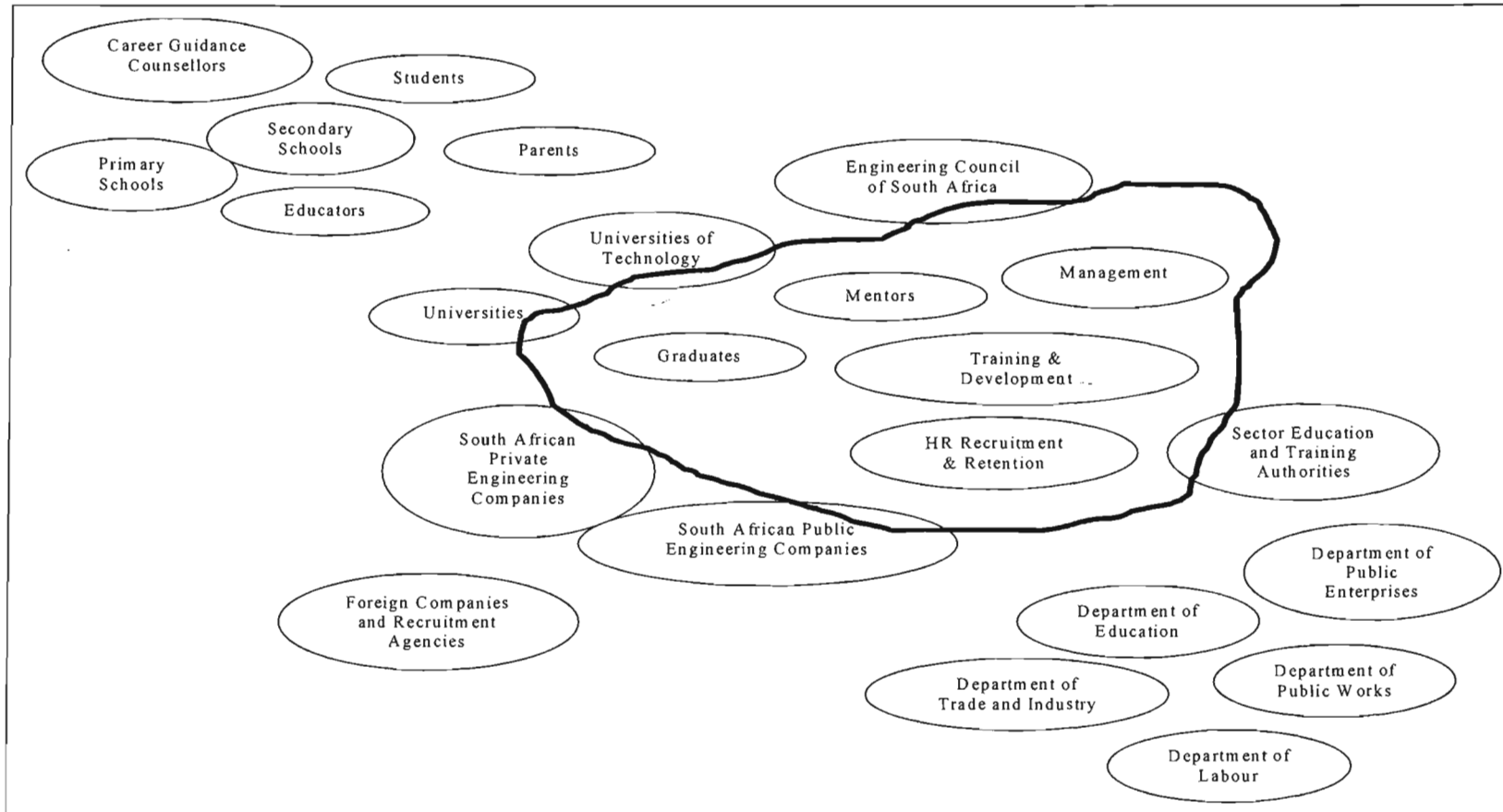


Figure 12 Systems Map of Engineering Skills in Eskom

The entities that make up the '*education system prior to tertiary education*' are shown in the top left part of Figure 12. In between the entities that make up the '*education system prior to tertiary education*' and the key stakeholders³⁷ within Eskom, there are tertiary education entities and ECSA.

In addition, the governmental departments including the Department of Education (DoE) is shown at the bottom right section. Finally, companies and organisations that are external to Eskom are depicted on the bottom left part of Figure 12.

The author noted that the drawing of the systems map isolated the governmental departments, especially the DoE, from the entities that they need to regulate, namely the primary, secondary and tertiary education institutions. Although the systems map was not intentionally drawn like this, it highlighted to the author of this dissertation one of the possible issues with the system under consideration i.e. there could be an inappropriate³⁸ amount of regulation between the DoE and the education institutions.

4.1.3 INFLUENCE DIAGRAM

The systems map provided in Figure 12 was extended to produce the influence diagram³⁹ provided in Figure 13. The systems map was altered⁴⁰ to essentially allow for the influence between the DoE and the education institutions to be more presentable on the influence diagram.

³⁷ Those within the boundary e.g. graduates.

³⁸ This requires further investigation as it could involve either an insufficient or excessive amount of regulation.

³⁹ Arrows are read as "influences" e.g. the top left arc is read "Career Guidance Counsellors" influence "Students".

⁴⁰ The author re-arranged the entities and removed one entity: Department of Public Works which, although it is instrumental to the alleviation of the general skills issue in South Africa, it is not significant in the discussion of Eskom's engineering skill shortage.

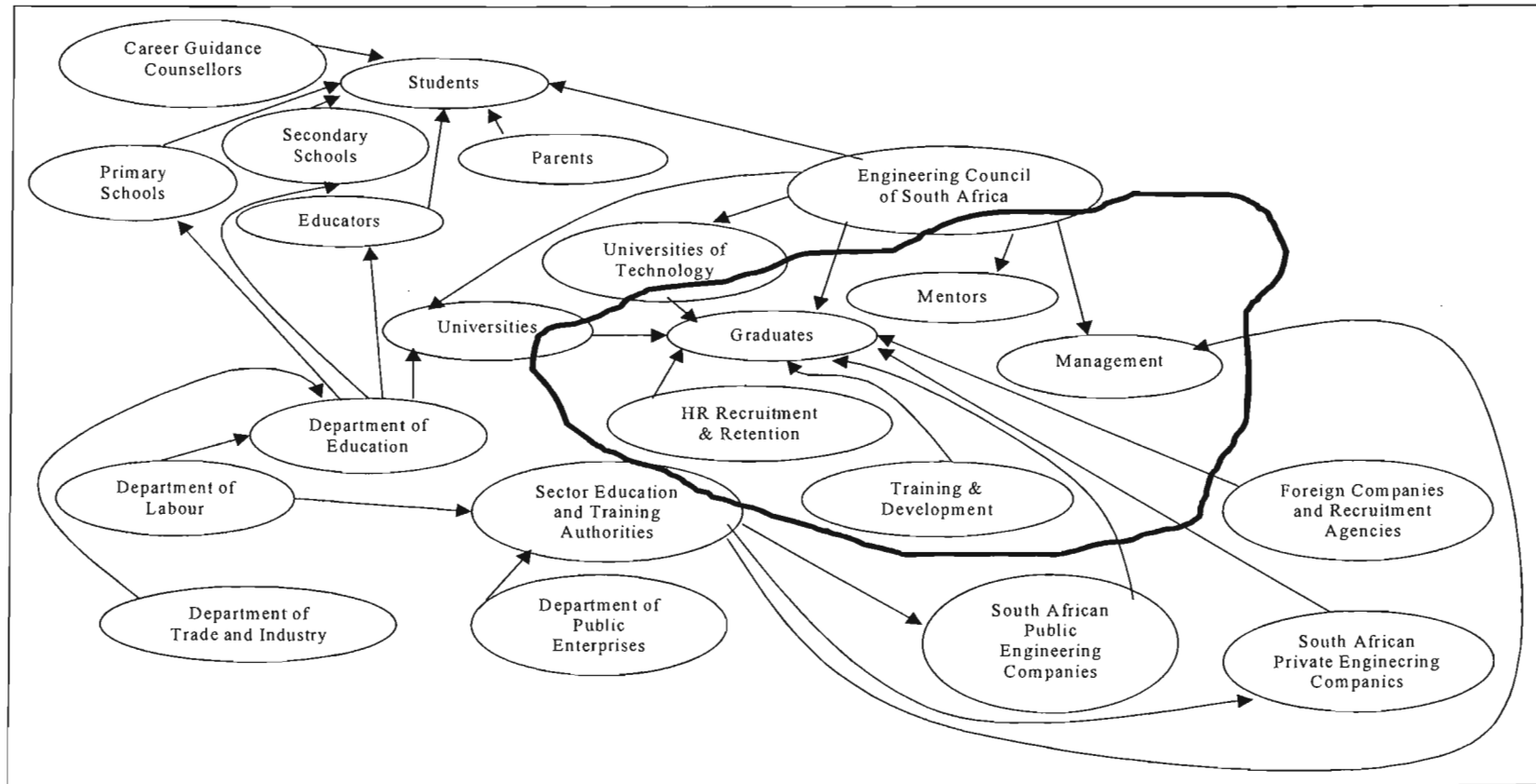


Figure 13 Influence Diagram of Engineering Skills in Eskom

By analysing Figure 13, the entities that are being most influenced from a number of sources are the graduates and students as shown by the number of arrows leading to these entities. In addition, the entities that are the most influential as shown by the number of arrows leading away from them are ECSA and the DoE. Furthermore, there seems to be a disconnect between the DoE and Sector Education and Training Authority (SETA). From these observations, the possible leverage points could be ECSA and DoE.

4.1.4 MULTIPLE CAUSE DIAGRAM

Figure 14 depicts the Multiple Cause Diagram for the Shortage of Engineering Skills in Eskom that was derived from Moodley (2006a).

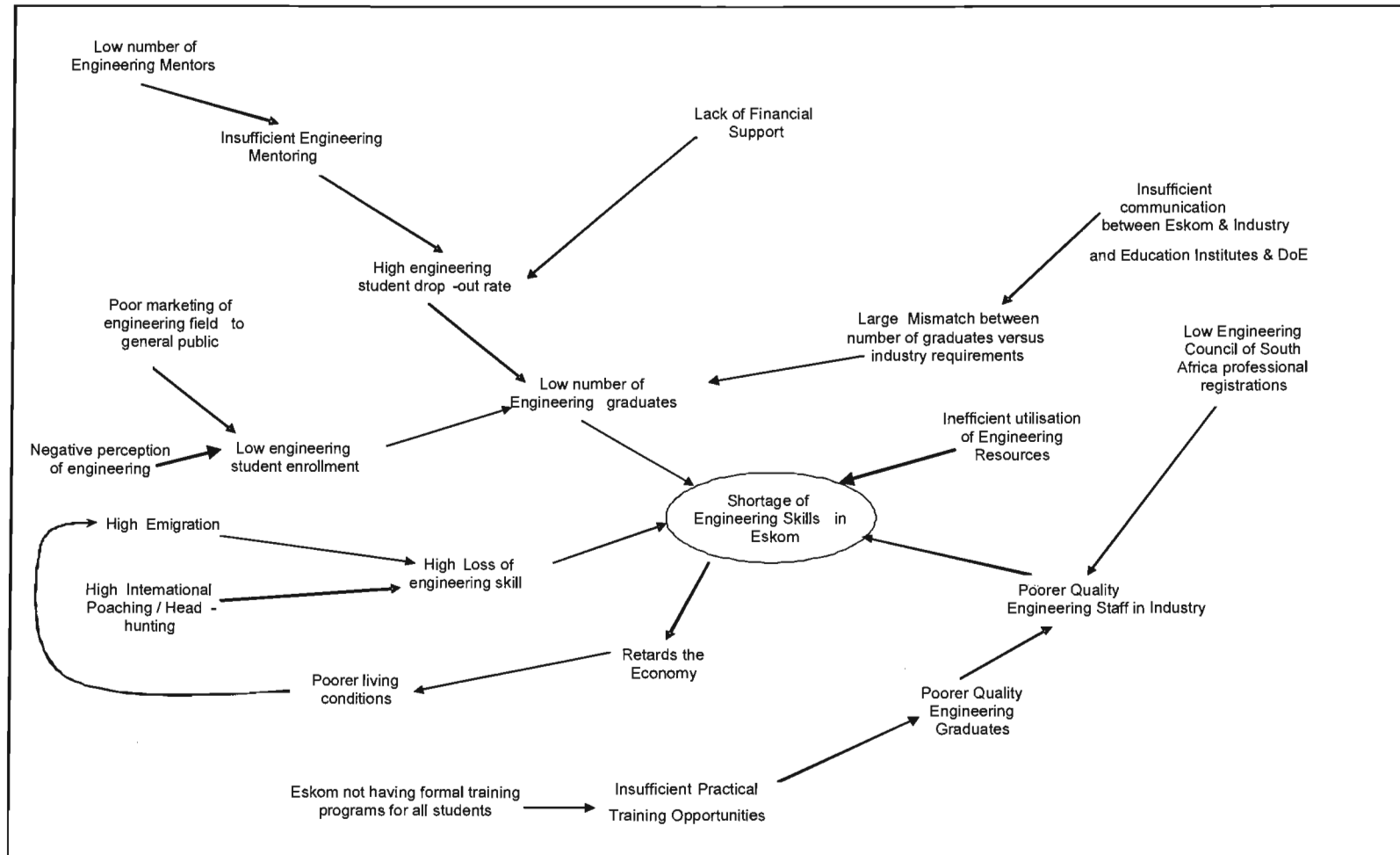


Figure 14 Multiple Cause Diagram for the Shortage of Engineering Skills in Eskom

From the multiple cause diagram provided in Figure 14, it can be seen that the shortage of engineering skills seems to be largely due to three causes, namely inadequately skilled engineering staff, low number of engineering graduates and loss of engineering skills.

With respect to the loss of engineering skills, it can be seen that the impact is a shortage of engineering skills and hence a retarded economy which in turn creates increased emigration due to poorer living conditions. However, if the shortage of engineering skills was alleviated by some means, this would provide the basis for an improvement to the economy and assist in lowering the emigration and the attrition of engineering skills. However, with the effect of globalisation, it can be expected that the loss of engineering skills will continue due to the existence of an international marketplace for engineering skills.

It is important to note that the author asserted that there is insufficient collaboration between Eskom and academia by indicating the causal relationship on the top right of Figure 14.

In addition to the above and with reference to Braun (2002), the author of this dissertation noted that there is resemblance to the *Limits to Growth* systems archetype and the lesser known *Attractiveness Principle*⁴¹ systems archetype. This indicated to the author of this dissertation that effort will need to be placed on identifying the multiple slowing actions and selecting the limits to the growth of the system that need to be addressed first.

Furthermore, the *Growth and Underinvestment* systems archetype resembles the situation of underinvestment in both Eskom's electricity capacity and the associated engineering skill to build the additional capacity. For many years the need to invest in new electricity capacity was met with a perception that this was unnecessary due to the adequate performance of Eskom in those years.

4.1.5 DRAFT SYSTEMS DYNAMICS MODEL

Having considered the information and new knowledge gained from preceding sections 4.1.1 to 4.1.4, the author produced a draft Systems Dynamics model as shown in Figure 15. The model depicted in Figure 15 is based on a model drawn up earlier in the research process, Moodley (2006b).

⁴¹ This archetype has, as part of its structure, multiple slowing actions and takes its name "...from the dilemma of deciding which of the limits to address first, that is, which is more attractive in terms of the future benefit to the desired results that are being pushed by the effort (or growing action)."

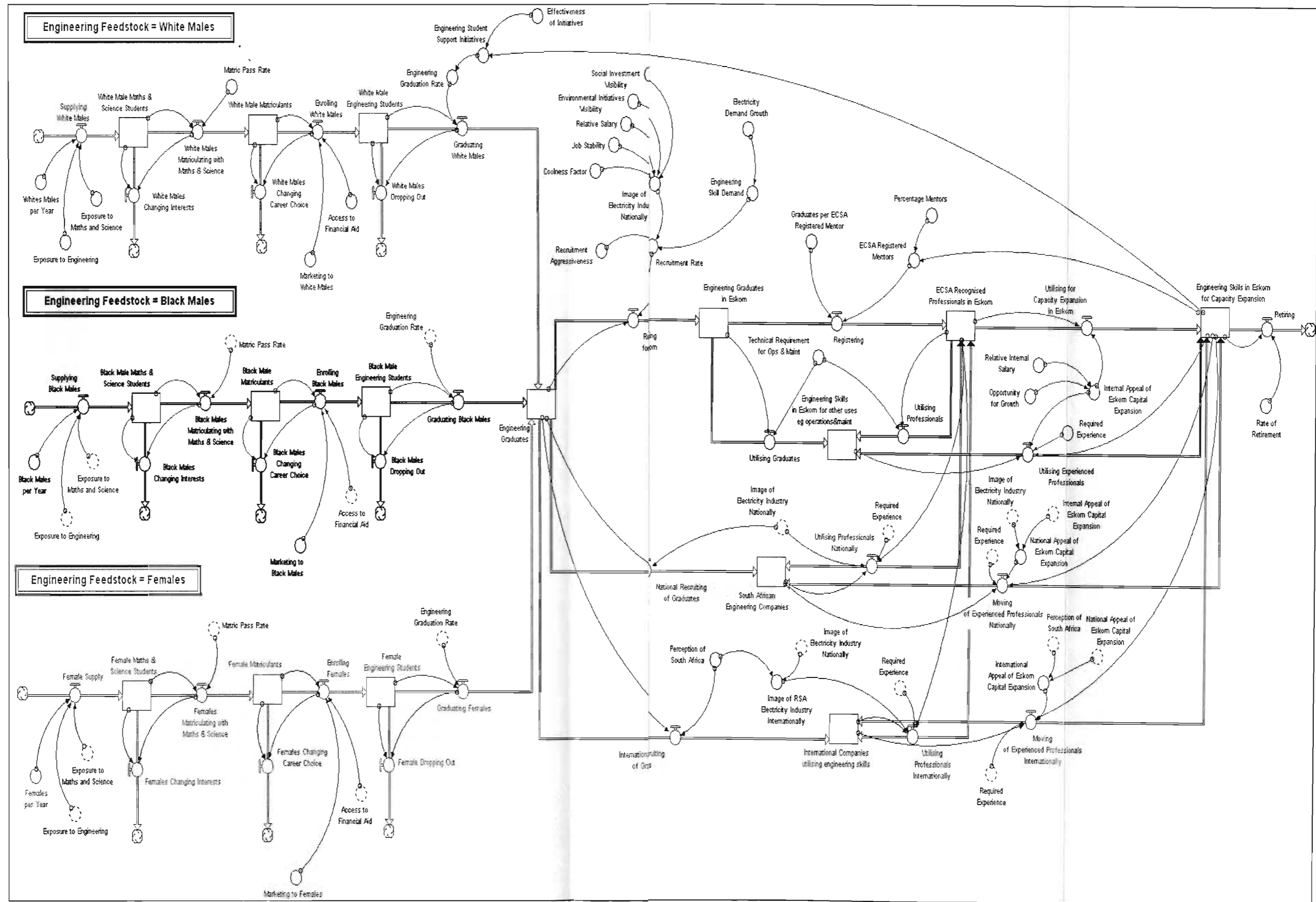


Figure 15 Draft Systems Dynamics Model depicting the Engineering skills in Eskom

4.1.5.1 THE USE OF ITHINK

The systems dynamics model provided in Figure 15 was developed using *ithink*: a systems dynamics modelling software package of ISEE Systems. The author of this dissertation made use of the systems dynamics modelling building blocks described in Table 9 (all quotes in Table 9 are from ISEE Systems (2004)).





#	Title	Purpose	Example from Figure 15
1	Stock	“Stocks are accumulations. They collect whatever flows into them, net of whatever flows out of them.” In addition, an initial value must be specified i.e. at time period zero, what is the starting value of the stock?	 Engineering Graduates
2	Flow	“The job of flows is to fill and drain accumulations. The unfilled arrow head on the flow pipe indicates the direction of positive flow.” In addition to ‘uniflows’ that only allow flow in one direction, there are ‘biflows’ that allow flow in both directions. For biflows, the filled arrow head specifies negative flow, whilst the unfilled arrow head specifies positive flow.	 Retiring
3	Converter	“The converter serves a utilitarian role in the software. It holds values for constants, defines external inputs to the model, calculates algebraic relationships, and serves as the repository for graphical functions. In general, it converts inputs into outputs.”	Engineering Graduation Rate 
4	Connector	These are the arrows on the diagram and “[a]s its name suggests, the job of the connector is to connect model elements.”	

Table 9 Summary of *ithink* model elements utilised in Figure 15

4.1.5.2 A DESCRIPTION OF THE DRAFT SYSTEMS DYNAMICS MODEL

Due to the under-representation of females and black males in South Africa, discussed in section 2.6.8, the left hand side of Figure 15 can be viewed as the supply side in which the three⁴² feedstocks that are providing the needed engineering graduates are sub-divided into white males, black⁴³ males and females⁴⁴. All three of these feedstocks go through a process of choosing mathematics and science at school, matriculating with mathematics and science, enrolling for engineering studies at tertiary education institutions and then finally graduating. It must be noted that losses are modelled through this process e.g. not all students choose mathematics and science in school.

On the other hand, the right hand side of Figure 15 can be viewed as the demand side in which the graduates that have been produced get utilised in industry. The demand side has been modelled as four grouped entities that make use of engineering graduates, namely Eskom's Capital Expansion Programme, Eskom's operate and maintain business, other South African industries and international industries.

Eskom's Capital Expansion Programme is given the main focus, in which engineering graduates are recruited, registered with ECSA as professionals and finally housed and retained in the Capital Expansion Programme's engineering resource pool. The other three entities are modelled as either supplementing or reducing the engineering resources that will be or are available for the Capital Expansion Programme.

Table 10 provides a summary of initial values (with references) as well as a description of the inlet and outlet flows for each of the stocks shown in Figure 15. In addition, Table 11 provides a summary of equations and constants for converters shown in Figure 15. Furthermore, a detailed listing of equations for the stocks and flows is provided in Appendix 2: Details of Systems Dynamics Models, Stocks & Flows of Draft Systems Dynamics Model.

⁴² If the model was to represent this part of reality more completely, there would need to be 8 feedstocks (= 2 sexes x 4 race groups). This would add more complexity to the model than necessary since, at the graduate level, the Indian feedstock tracks the Black feedstock closely and the Coloured feedstock only contributes a constant 3% to the total graduates. For the purposes of this research study, the simplification of the model to 3 feedstocks is used.

⁴³ This includes Blacks, Indians and Coloureds.

⁴⁴ This includes both Black (broader definition) and White females.

It must be noted that no time lags were implemented in this model e.g the time it takes to produce a graduate (3 to 6 years). In addition, it must also be noted that although a feedback loop is shown in the top left part of Figure 15 that tries to improve the engineering graduation rate by the use of engineering student support initiatives by Eskom, the number of engineering graduates remains at the current level and the engineering skills shortage in Eskom is still being experienced. Therefore, this initiative has been zero-rated.

#	Stock Name	Initial Value	Description
1	Black Male Maths and Science Students	<i>Inflow</i>	The initial values of these stocks have been set to the initial inflow e.g. for . <i>Black Male Maths and Science Students</i> , the initial value = <i>Supplying Black Males</i> . The effect of students that have failed in the previous year are ignored for a simplified analysis. Outflows are modelled as black male students changing interests, changing career choices and dropping out from tertiary education.
2	Black Male Engineering Students	<i>Inflow</i>	
3	Black Male Matriculants	<i>Inflow</i>	
4	ECSA Recognised Professionals in Eskom	0	The initial number of <i>ECSA Recognised Professionals in Eskom</i> that have not been allocated to operation & maintenance or the power generation capacity expansion programme is set to zero.
5	Engineering Graduates in Eskom	50	Engineering Council of South Africa (2005) shows that the number of engineering graduates per year in South Africa works out to be ~4300 per year. This figure is based on an initial input of ~1% of these 4300 engineering graduates into Eskom ⁴⁵ .
6	Engineering Skills in Eskom for Capacity Expansion	400	This figure was confirmed with Clive Le Roux during an interview for this research.
7	Engineering Skills in Eskom for other uses e.g. operations & maintenance	9000	This figure was stated by Clive Le Roux during an interview for this research.

⁴⁵ The following statement appears on page 30 of Eskom's 2008 annual report: "Estimated figure, detailed split of engineering and technical trainees and bursars is not available."

#	Stock Name	Initial Value	Description
8	Engineering Graduates	<i>Inflow</i>	The initial values of these stocks have been set to the initial inflow e.g. for . <i>Female Maths and Science Students</i> , the initial value = <i>Supplying Females</i> . The effect of students that have failed in the previous year are ignored for a simplified analysis. Outflows are modelled as female students changing interests, changing career choices and dropping out from tertiary education.
9	Female Engineering Students	<i>Inflow</i>	
10	Female Maths & Science Students	<i>Inflow</i>	
11	Female Matriculants	<i>Inflow</i>	
12	International Companies utilising engineering skills	30 000 000	Utilising the figures provided by Reder (2006), this figure can be calculated: ~1 500 000 engineering graduates in the world per year x 40 years of productive life x 50% (estimated value) retention in the engineering field.
13	South African Engineering Companies	80 000	Utilising the figures provided by Engineering Council of South Africa (2005) for the number of engineering graduates per year in South Africa, this figure is a calculated figure: ~4000 engineering graduates x 40 years of productive life x an estimated 50% retention in the engineering field = 80000.
14	White Male Maths & Science Students	<i>Inflow</i>	The initial values of these stocks have been set to the initial inflow e.g. for . <i>White Male Maths and Science Students</i> , the initial value = <i>Supplying White Males</i> . The effect of students that have failed in the previous year are ignored for a simplified analysis. Outflows are modelled as white male students changing interests, changing career choices and dropping out from tertiary education.
15	White Male Matriculants	<i>Inflow</i>	
16	White Male Engineering Students	<i>Inflow</i>	

Table 10 Summary of equations and initial values of the stocks and flows

#	Coverter Name	Value	Description
1	Access to Financial Aid	60 / 100	<p>It can be shown using the figures in the Department of Education's 2005 Education Statistics that just under 60% of the matriculants with the required mathematics and physical science in either higher grade or standard grade are first year enrollments in Science, Engineering and Technology fields.</p> <p>These students seek the required tertiary education finance through various means, namely personal loans, family support, self financing and financial aid offered by government through the National Student Financial Aid Scheme (NSFAS). In addition, the percentage of students that have access to financial aid for their tertiary studies is stated to be 20 % of those that require financial assistance, Van Harte (2006).</p> <p>Furthermore, although there could be a racial differentiator in this variable, efforts of the NSFAS have sought to negate this effect and therefore this racial differentiator will not be addressed.</p>
2	Black Males per Year	203000	Department of Education (2005) provides a figure of 230492 male Grade 12 students and using the demographic distribution provided in the 2001 census, Cilliers (2006), the number of Black Male Grade 12 students is 203000 (rounded-off to the nearest 1000).
3	Coolness Factor	80 / 100	Braehmer <i>et al</i> (2000) shows that engineering features as one of the top fields that youth want to get training in. The perception of engineering as a value contributor, fun and prestigious discipline has increased with the marketing of science, engineering and technology in a television program such as "Hip 2B ² " (Hip to be Square) and Eskom's Young Scientist Expo.

#	Coverter Name	Value or Equation	Description
4	ECSA Registered Mentors	Engineering Skills in Eskom for Capacity Expansion * Percentage Mentors	This is a calculated figure based on the number of engineering staff in Eskom's Capacity Expansion and the percentage of registered mentors.
5	Effectiveness of Initiatives	5 / 100	The initiatives will provide secondary support (of short duration) to the students. The effectiveness of these initiatives in terms of improving the pass rate are therefore seen to be minor (5%)..
6	Electricity Demand Growth	4.9 / 100	Current annual electricity demand growth, Eskom (2007a).
7	Engineering Student Support Initiatives	Effectiveness of Initiatives * Engineering Skills in Eskom for Capacity Expansion / INIT(Engineering Skills in Eskom for Capacity Expansion) * 0	<p>This is a weighted figure of how effective the initiatives are in assisting engineering students in improving the pass rate. The weighting was based on the ratio of the current number of engineering staff in Eskom's Capacity Expansion effort versus the initial number. This implies that if the number of engineering staff increases, the Engineering Student Support Initiatives will also increase.</p> <p><u>Note that this has ben set to zero for the draft model.</u></p> <p>Engineering Student Support Initiatives could take the form of mentoring, additional tutoring, time management training etc.</p>
8	Engineering Graduation Rate	min((15 / 100)+Engineering Student Support Initiatives,75 / 100)	The engineering graduation rate is allowed to vary from 15% to 75% depending on the effectiveness of the Engineering Student Support Initiatives. Engineering Council of South Africa (2005) presents a comparative graduation rate of 11.62% for universities and universities of technology in 2004.

#	Coverter Name	Value or Equation	Description
9	Engineering Skill Demand	Electricity Demand Growth / (4.9 / 100)	The demand figure is calculated as a linear ratio of the current Electricity Demand Growth versus the current 4.9% Electricity Demand Growth, Eskom (2007a).
10	Environmental Initiatives Visibility	60 / 100	This figure depicts the visibility of Eskom's pro-environmental initiatives. The basis of this value is due to Eskom publishing its environmental impact in its annual report and Eskom supporting public participation in Environmental Impact Assessments (EIAs) of projects undertaken by Eskom.
11	Exposure to Engineering	5 / 100	The overall exposure of students to engineering is fairly low when compared to other long-standing disciplines such as law and medicine. One can consider the number of mainstream law and medical programs versus engineering. The figure of 5% represents this relatively low exposure.
12	Exposure to Maths and Science	32 / 100	An overall percentage figure of the students taking Mathematics and Science in matric as quoted by the Department of Education in 2005..
13	Females per Year	275000	Department of Education (2005) provides a figure of 275000 female Grade 12 students (rounded-off to the nearest 1000).
14	Graduates per ECSA Registered Mentor	2	As part of Continual Professional Development (CPD), a person registered in one of the professional categories defined by ECSA, can elect to gain one credit out of five per year of CPD by mentoring candidate professionals for 50 hours per year (formally). Based on the work load of the mentor and technical depth required by a mentee, the mentor could divide these 50 hours between 2 people (without necessarily compromising the quality of mentorship).

#	Coverter Name	Value or Equation	Description
15	Image of RSA Electricity Industry Internationally	Image of Electricity Industry Nationally * Perception of South Africa	The image of South African Electricity Industry on an international level is dependant on the image of South African Electricity Industry at a national level.
16	Image of Electricity Industry Nationally —	MEAN(Coolness Factor, Environmental Initiatives Visibility, Job Stability, Relative Salary, Social Investment Visibility)	This is an average of a number of soft variables.
17	Internal Appeal of Eskom Capital Expansion	Opportunity for Growth * Relative Internal Salary	The internal appeal of Eskom Capital Expansion is modelled to be dependant on the perceived opportunity to grow and the relative salary as compared to other parts of Eskom that require engineering skill. This determines how much of engineering skill, internal to Eskom, migrates to the Capital Expansion Programme.
18	International Appeal of Eskom Capital Expansion	National Appeal of Eskom Capital Expansion * Perception of South Africa	The international appeal of Eskom's Capital Expansion programme is modelled as being dependant on the perception of South Africa (economically, politically, citizen confidence etc.) and the national appeal of Eskom's Capital Expansion Programme.
19	Job Stability	80 / 100	Eskom is essentially a government-owned organisation and as such, job stability is usually higher than that of the private industry. In addition, the electricity industry in terms of revolutionary technology changes, is fairly static. Job stability is therefore high.

#	Coverter Name	Value or Equation	Description
20	Marketing to Females	20 / 100	As described in section 2.6.8 : Women and Other Under-Represented Groups in Engineering, women are still under-represented in engineering. Currently the engineering discipline sees that its ability to attract and produce graduate women engineers hovers around the 20% mark.
21	Marketing to Black Males	70 / 100	As described in section 2.6.8 : Women and Other Under-Represented Groups in Engineering, black men are still under-represented in engineering. However, great strides have been made since the days of Apartheid, when only a handful of black male engineers graduated. Although much work (in the form of marketing and support) still needs to be done to get full representation, a figure of 70% describes the current level.
22	Marketing to White Males	95 / 100	The “face of engineering” as described in section 2.6.8 : Women and Other Under-Represented Groups in Engineering, has been that of a white male for many years. Although this is changing, marketing which attracts white males remains high. A figure of 95% is used to represent this.
23	Matric Pass Rate	59 / 100	The Department of Education (2005) provides this overall average for those that passed mathematics and physical science on the higher grade and standard grade, respectively. Both of these subjects are pre-requisites for engineering studies in a tertiary education institute.

#	Coverter Name	Value or Equation	Description
24	National Appeal of Eskom Capital Expansion	Internal Appeal of Eskom Capital Expansion * Image of Electricity Industry Nationally	This is modelled to be dependant upon the internal appeal of Eskom's Capital Expansion programme and the image of the electricity industry at a national level.
25	Opportunity for Growth	110/100	The newer technology explored in the power generation capacity expansion programme offers the engineering personnel the possibility of an increased personal development rate when compared to normal operations and maintenance work. The opportunity for personal growth and development is taken to be 10% greater than these other areas in Eskom.
26	Percentage Mentors	5 / 100	Approximately 5% of the total engineering complement in Eskom's Capital Expansion group are registered mentors.
27	Perception of South Africa	60 / 100	The perceptions of South Africans has been gauged in terms of preparedness in a number of sectors for the FIFA World Cup in 2010, SAinfo (2007). A weighted average, with a focus on electricity resulted in an approximate 60% confidence level.
28	Rate of Retirement	2.5 / 100	Using the figure of 40 years for the normal working life of most adults, in 40 years the stock of engineering personnel will have depleted to zero if no input was received. Therefore, 2.5% of the total engineering complement will retire every year for a period of 40 years

#	Coverter Name	Value or Equation	Description
29	Recruitment Rate	Image of Electricity Industry Nationally * Recruitment Aggressiveness * Engineering Skill Demand	The rate of recruitment that Eskom can achieve is modelled as being dependant on the image of the electricity industry at a national level, Eskom's ability to employ aggressive recruitment strategies and the demand for engineering skill.
30	Recruitment Aggressiveness	20 / 100	Prior to the power generation capacity expansion programme, Eskom did not use all media sources (such as radio) to advertise for vacancies. In addition, Eskom lags behind the private industries when it comes to bursar recruitment and support pogrammes. This Recruitment Agressiveness figure is set at 20% of what Eskom's potential is.
31	Relative Internal Salary	110/100	The relative internal salary of Capital Expansion Programme engineering staff versus other Eskom engineering staff is set at 10% higher. This is sensitive information and there is no official source for this information. It is based on the personal experience of the author of this dissertation.
32	Relative Salary	60 / 100	This is the salary level of the electricity industry to other South African industries. This is sensitive information and there is no official source for this information. It is based on the personal experience of the author of this dissertation.

#	Converter Name	Value or Equation	Description
33	Required Experience	10 / 100	Due to the nature of Eskom's work prior to the power generation capacity expansion programme, only a small part of the work (approximately 10%) involved actual engineering and the rest involved operations and maintenance work. Therefore a number of candidates within Eskom did not have the requisite experience, although they had exposure to Eskom's operations.
34	Social Investment Visibility	60 / 100	This figure depicts the visibility of Eskom's Social Investment initiatives. The basis of this value is due to the work of the Eskom Development Foundation and the publishing of its effort in its annual report.
35	Technical Requirement for Ops & Maint	5 / 100	The requirement for engineering skills to be utilised in the maintenance and operation environment is set at 5% of the engineering graduates in Eskom.
36	Whites Males per Year	25000	Department of Education (2005) provides a figure of 230492 male Grade 12 students and using the demographic distribution provided in the 2001 census, Cilliers (2006), the number of White Male Grade 12 students are 25000 (rounded-off to the nearest 1000).

Table 11 Summary of equations and constants of the converters

The graph provided in Figure 16 provides a time series plot (hereafter referred to as a Behaviour over Time (BoT) graph) of the following 4 stocks:

1. Engineering Graduates (in South Africa) : initially increases and then levels off at just under 5100 graduates.
2. Engineering Graduates in Eskom : shows a steady increase of graduates within Eskom to just over 4000 graduates.
3. Engineering Skills in Eskom for the Capacity Expansion Programme: shows a steady increase of graduates within Eskom to just over 4000 graduates.
4. Engineering Skills in Eskom for other uses i.e. Operating and Maintenance : initially is depleted by use of these resources in the Capacity Expansion Programme however these resources start to recover after year 8.

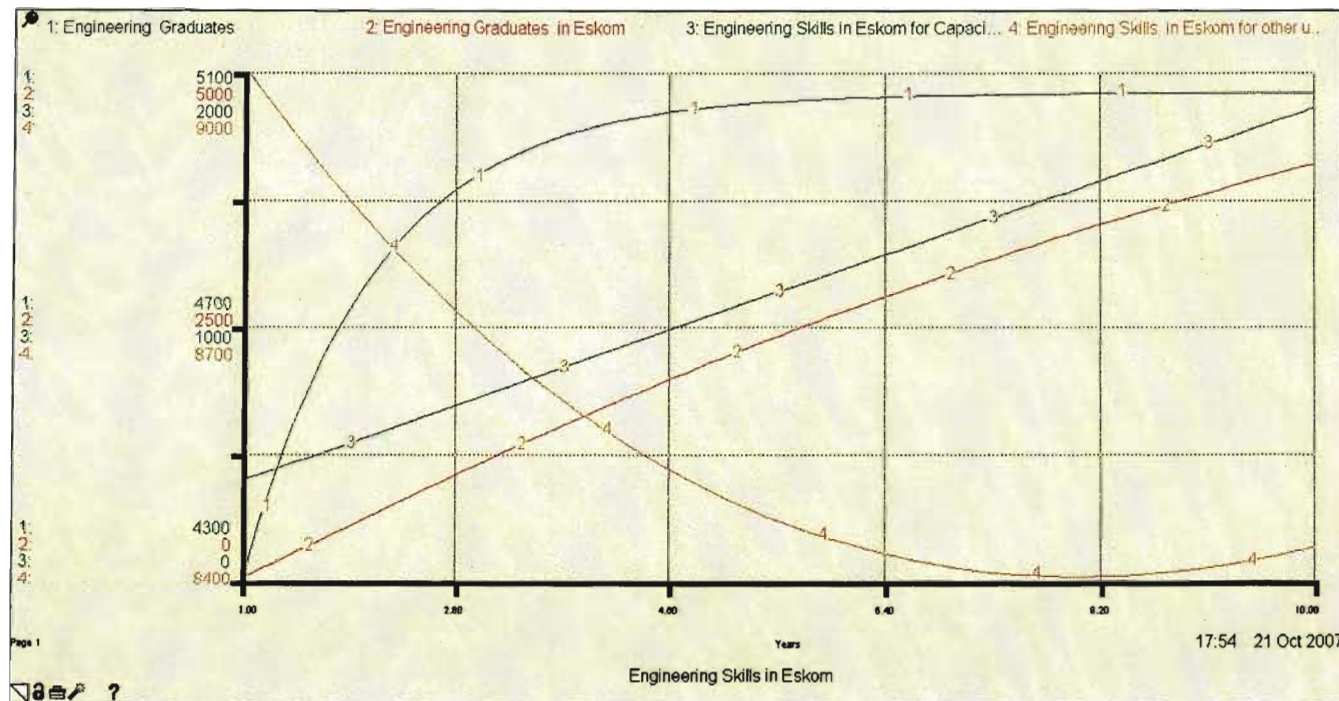


Figure 16 Engineering Skills in Eskom for the Capital Expansion Programme

This BoT graph allowed the author of this dissertation to make the observation that the number of engineering personnel available for Eskom's Capacity Expansion Programme will double from the now 400 people to 800 people in 3 years i.e. by calendar year 2011.

In addition, the number of graduates in South Africa and Eskom builds steadily over the years. However, in both cases, it is the author's opinion that these graduates should not be growing at this rate since as soon as these graduates get produced, they should be utilised in industry. This is suggestive to the author of this dissertation that industry is not absorbing available engineering skills albeit that they are entry-level skills. Further to this, there is a physical limit on the number of graduates that can be produced by the tertiary education institutes due to their own capacity limitations.

Furthermore, the skills within the Eskom's operate and maintain domain is utilised in the capacity expansion effort. Eskom's operate and maintain engineering skills diminishes until at such time that the graduates replenish and then surpass this loss. It must be noted that this draft model has not taken consideration of the moratorium placed on the utilisation of Eskom Generation skills for the capacity expansion effort.

Figure 17 provides the numbers of students and engineering graduates as calculated by the systems dynamics model. It emphasises the problem of not being able to get enough students through the system, having started with over 186 110 students who choose maths and science and ending up with just over 4339 engineering graduates. This translates into a mere 2 % success rate.

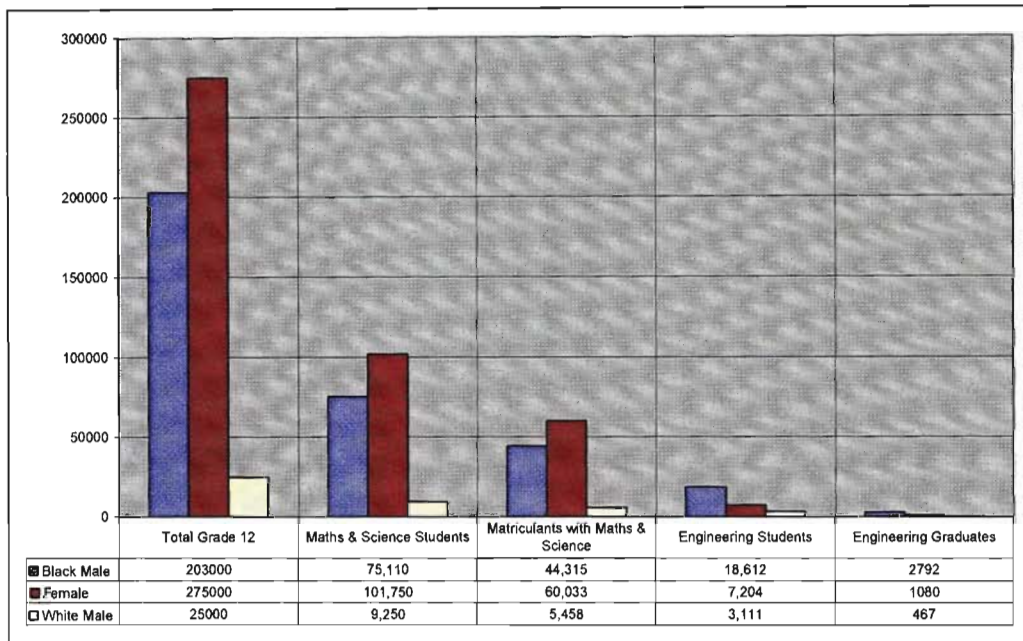


Figure 17 System Dynamics Model: Number of students and graduates

In addition, Figure 18 provides the percentage comparison of the different feedstocks as calculated by systems dynamics model constructed by the author of this dissertation.

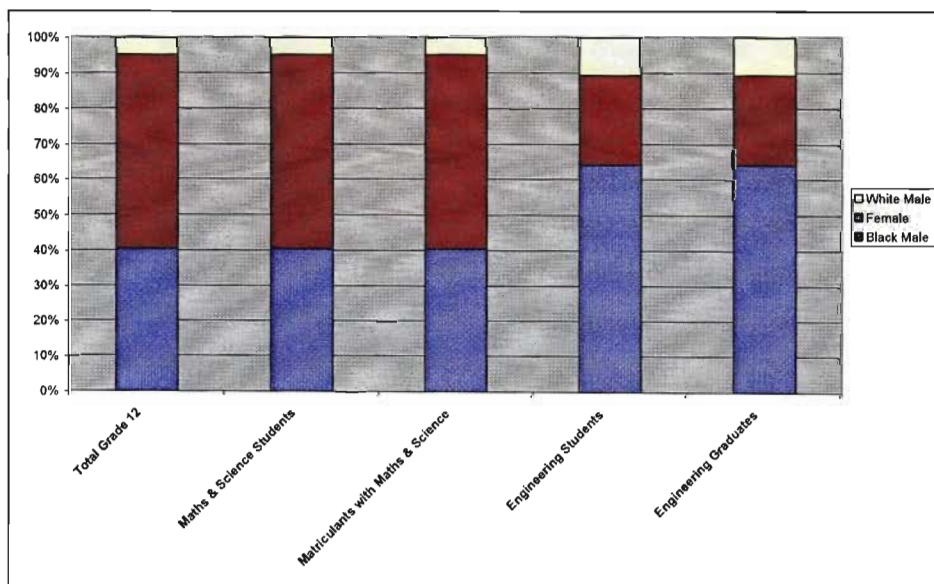


Figure 18 System Dynamics Model: Percentage of students and graduates

Figure 18 illustrates that the percentage of female engineering graduates is much lower than that of the male engineering graduates, especially considering that there are more females than males at the Grade 12 level.

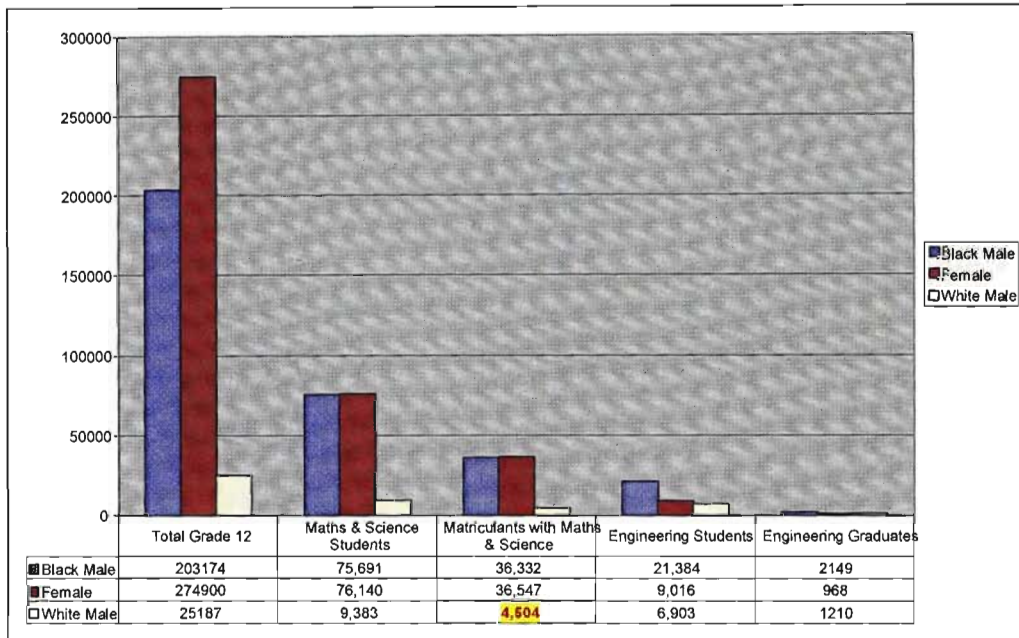


Figure 19 Actual figures of students and graduates

Please note the discrepancy listed in the footnote⁴⁶ and highlighted in the data table provided in Figure 19. Although the engineering graduates figure shows that black males with 2149, is the dominant supply, this must be tempered with fact that if only university engineering graduates are considered, the number of black males still lags behind the number of white males, 380 to 570, respectively. Females add another 227 university engineering graduates.

⁴⁶ The exception is “Matriculants with Maths and Science” since the figure for males is not broken into the different race groups in Department of Education (2005), an average pass rate of 48% was used for the estimation. The actual pass-rate is higher for white males, since there is a discrepancy between the 6903 enrollments versus the estimated matriculant figure of 4504.

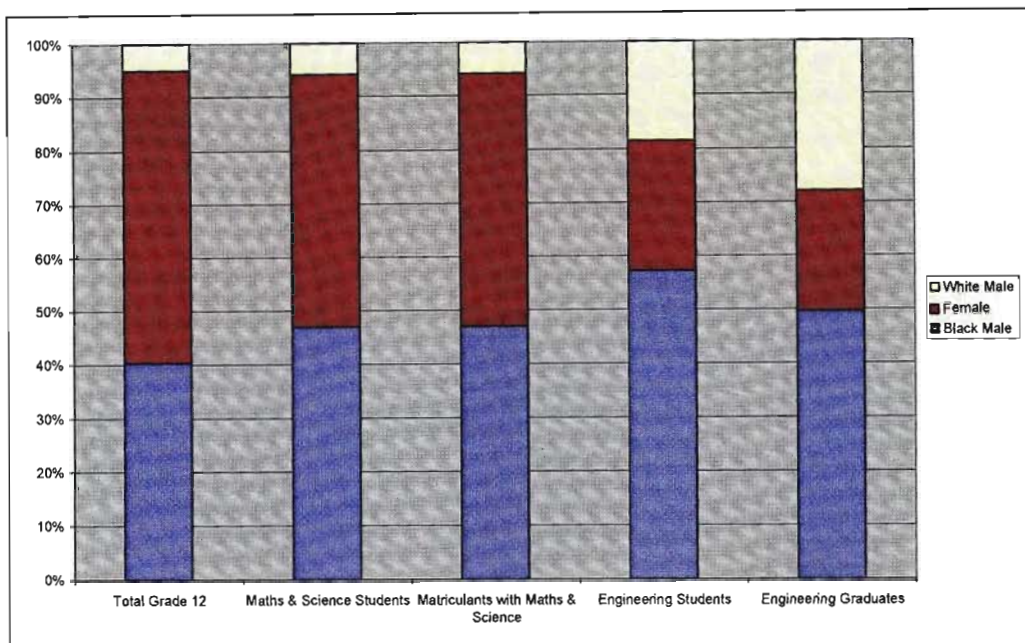


Figure 20 Actual⁴⁶ percentage figures of students and graduates

The percentage figures in Figure 20 confirms the distribution numbers of graduates i.e. black males are the dominant supply whereas females continue to be under-represented. The number of males to females at the grade 12 matriculation level (“Matriculants with Maths and Science”) is almost parity. However, at the graduate level, males outnumber the females at a ratio 4 to 1. The author takes note that the drop in the representation of females is noticed at the enrollment stage i.e. although they have the pre-requisite maths and science subjects, they choose other career fields.

Finally, Figure 21 compares the numbers produced by the systems dynamics model and the actual numbers of students and engineering graduates. The author of this dissertation suggests that the difference in the number of females at the “Maths and Science Students” level could be attributed to the systems dynamics model not taking into account the social factors that influence the choice of school-level subjects amongst the gender groups.

The difference at the grade 12 matriculation level (“Matriculants with Maths and Science”) could be attributed to the the systems dynamics model not taking into account the lower pass rate for males at this level when compared to females. The difference in females at this level could be attributed to the compound effect of the previous level’s discrepancy.

The discrepancy at the next level i.e. “Engineering Students” are all showing that the systems dynamics model is calculating a value under the actual figures. The model could not be taking into consideration the affinity to technical subjects that white males have

(due, in part, to the better educational facilities offered to this group during Apartheid). In addition, the attraction to an engineering career could have been underestimated (to a lesser extent) for females and black males.

Furthermore, the number of black males and females at the graduate level is more than the actual figures. This could be attributed to lower pass rates amongst these groups in reality than that of white males. Finally, the low number of white male graduates as calculated in the model, could be a compounded error from the prior “Engineering Student” level.

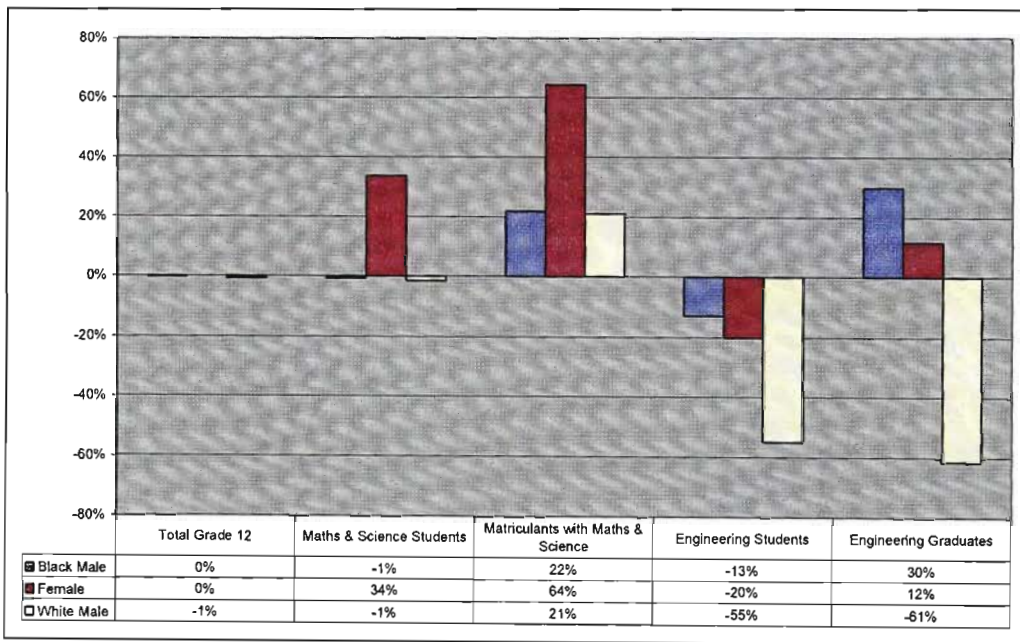


Figure 21 Comparison: Systems Dynamics Model versus Actual

4.2 SUMMARY OF INTERVIEW DATA

A total of 9 stakeholders were interviewed individually (face-to-face) with interview durations ranging between 90 minutes and 120 minutes per stakeholder. The interviewees were selected using the criteria defined in section 3.2.2 on page 4 in order to get a representative sample of perspectives on engineering skills shortage in Eskom for the capacity expansion programme.

For each of the 9 stakeholders, the interview process followed was as per Table 12.

#	Activity	Description
1	Personal Details	The following questions are asked: Age ? Qualifications: institute and when ? Years in Eskom ? Years in Enterprises Division and EED ? Title of position currently filled ?
2	Pre-prepared questions	The questions asked in this segment of the interview are selected as per Table 18 of Appendix 1: List of Questions per Interviewee.
3	Current Interventions	The interviewee's perspective on the impact of current interventions as listed in Table 2: Description and classification of current interventions
4	Alternative Interventions	The interviewee was requested to suggest alternative interventions to those identified in Table 2: Description and classification of current interventions
5	Draft Systems Dynamics Model	The draft systems dynamics model provided in Figure 15 on page 4 was presented to the interviewee. Suggestions for improvement to this systems dynamics model was sought from the interviewee.
6	Other Suggestions and Comments	Apart from the guided responses sought from the interviewee on alternative suggestions and improvements to the systems dynamics model, an unguided response was sought from the interviewee on any other suggestions and comments for the author of this dissertation to consider.

Table 12 Interview process per interviewee

It must be noted that of the 9 interviewees, none chose to remain anonymous. A summary of the responses from each of the interviewees is provided in Appendix 4: Summary of Interviewees' Responses.

In addition, it must also be noted that although the author of this dissertation identified a number of interventions that Eskom has currently undertaken (Table 2: Description and classification of current interventions), there were interventions already undertaken by Eskom that interviewees identified and were not originally considered by the author of this dissertation.

The other current interventions that were identified by the interviewees are provided in Table 13:

#	Intervention Title	Description	Long / Medium / Short Term	Interviewee
12	Use of retirees	Former Eskom retirees providing mentorship.	Short	Christoph Kohlmeyer
13	Eskom Internal Resource Usage	Utilising resources from O&M i.e. Generation, Transmission or Distribution.	Short	Christoph Kohlmeyer
14	Use of Expatriates	Utilising the skill of former South Africans.	Short	Johannes van Tonder
15	Importing Resources	Importing skills from countries like India and China.	Short	Zubair Moola

Table 13 Other current interventions identified by interviewees

These additional interventions were appended to the list of interventions in Table 14: Summary of Perceived Impact of current interventions undertaken by Eskom.

4.2.1 PERSPECTIVES ON THE IMPACT OF CURRENT INTERVENTIONS

#	Interviewee	Accelerated Recruitment Drives	Mentorship & Training Programme	Engineering Processes	Improved Systems	Partnership: Other Companies	GARP & TASK	Bursaries	Partnership: Higher Education	Partnership: Government	Eskom University	Eskom Expo for Young Scientists	Utilising Retirees	Eskom Internal Resource Usage	Expatriates	Importing Resources	Summary per Interviewee ⁴⁷
1	Christoph Kohlmeyer	+1	-1	-1	-1	0	-1	-1	+1	0	-1	+1	+1	0	NE	NE	-2
2	Johannes van Tonder	0	-1	-1	0	-1	+1	+1	0	0	+1	+1	+1	-1	0	NE	+1
3	Clive Le Roux	0	-1	-1	-1	-1	+1	-1	0	+1	-1	+1	0	0	0	NE	-3
4	Samantha Kali	+1	0	-1	-1	-1	-1	+1	+1	0	+1	+1	0	+1	0	NE	+2
5	Eugene Motsoatsoe	+1	-1	-1	-1	+1	+1	-1	+1	0	+1	+1	+1	0	-1	NE	+2
6	Zubair Moola	+1	-1	0	+1	+1	0	+1	+1	0	0	+1	+1	+1	+1	-1	+7
7	Dieter Huppe	0	-1	-1	-1	-1	0	-1	0	+1	-1	+1	+1	0	-1	0	-4
8	Elsie Pule	+1	+1	0	0	+1	0	+1	+1	+1	0	+1	0	NE	+1	+1	+9
9	John Gosling	+1	-1	-1	-1	0	0	+1	+1	+1	0	+1	+1	-1	0	-1	+1
	Summary per Intervention ⁴⁷	+6	-6	-7	-5	-1	+1	+1	+6	+4	0	+9	+6	0	0	-1	+13

Table 14 Summary of Perceived Impact of current interventions undertaken by Eskom

Please note that NE is “not evaluated” i.e. the question was not posed to the interviewee since the intervention was only introduced through a subsequent interviewee or the time schedule did not allow for the question to be posed to the interviewee.

⁴⁷ Overall assessment of interviewee’s perspective on the impact of the current interventions per interviewee and per intervention. It is a simple arithmetic addition of all the perceived impact of current interventions i.e no weighting was considered.

From Table 14, it can be seen that the perception of the interviewees were that the top interventions in terms of a positive impact on the alleviation of engineering skill shortages are *Eskom Expo for Young Scientists, Utilising Retirees, Partnership with Higher Education Institutions* and *Accelerated Recruitment Drives*. In addition, the *Partnership with Government* is perceived to be positive.

On the other hand, those interventions that the interviewees perceived as having a negative impact on the the alleviation of engineering skill shortages are *(Lack of) Engineering Processes, Mentorship & Training Programme* and *Improved Systems*.

In addition, it is of significance that there are mixed feelings about the impact that the Eskom university will have mainly due to a lack of understanding of the concept. Furthermore, *Bursaries, the Utilisation of Internal Resources, Expatriates* and the *Importing of Resources* received mixed responses with essentially positive and negative responses.

4.2.2 PROPOSED INTERVENTIONS

Apart from the responses collected from the interviewees on the current interventions, the interviewees were requested to propose alternative interventions. Of significance is that it was stated that Eskom is utilising a resourcing strategy titled as “7 Bs”, Letlape (2007). Table 15 describes this resourcing strategy which is made up of 7 elements (all quotes in Table 15 are from Letlape (2007)).

#	Element	Description of Resourcing Strategy Element
1	Birth	“These are pipeline initiatives starting at primary to secondary school and tertiary level. It includes amongst others Learnerships etc.”
2	Borrow	“When the organisation realises that it does not have capacity, that an activity is not considered as core, where the required activity might be required as a once off even be short term and high labour intensive, this option then becomes relevant.” i.e. the resource is borrowed from other organisations.
3	Bridge	“Where project related resources are required it is not always necessary to consider permanent resourcing so this option can be used. This option involved secondments and redeployments.”
4	Bind	“This option is a proactive manner of attracting those potential candidates who were not necessarily looking for jobs in the company. Activities of branding the organisation are used. Eskom annually drives Career exhibitions to attract the relevant resources.”
5	Boost	“This option is about creating value for the employee by creating growth opportunities for employees through talent management, development programmes and succession management.”
6	Buy	“This option looks [at] resourcing from the external market as well as internal movements. Eskom has implemented a blended recruitment strategy that does not only attract “active” candidates but also “passive” candidates. The strategy is geared to ensure that service delivery is measured for each activity in the recruitment value chain to eliminate duplicated external advertising and resource quickly.”
7	Build	“Eskom will always focus on the upliftment of Eskom employees as its first priority. Internal staff movements create opportunities for career progression, but transfer the skills shortage issues from one environment to another, hence the need to recruit a strong pipeline from the external market.”

Table 15 Eskom's 7-Bs Resourcing Strategy

The alternative interventions suggested by the interviewees are tabulated⁴⁸ in Table 16. The approach taken to summarise these alternative interventions was to classify them according to the “7 Bs” resourcing strategy that Eskom is utilising. If the intervention could not be classified into at least one of the 7 elements, it was classified as “Other”.

Reference can be made to Appendix 4: Summary of Interviewees’ Responses to determine the interviewee who suggested the intervention. Where there is a number greater than one for the specific intervention, it signifies the number of interviewees that suggested the intervention and where there are two numbers, it signifies that the intervention is applicable to both of the selected elements of the 7-Bs strategy.

#	Intervention	Birth	Borrow	Bridge	Bind	Boost	Buy	Build	Other
1	Job Description: Defined								1
2	Information: Improved ability to find								1
3	Commissioning Experience							1	
4	Project Management: Additional Experience	2							
5	Open Days at Universities				1				
6	Mentor, assignment thereof							5	
7	Generation Skills Development Programme, utilisation thereof							3	
8	Secondment to Original Equipment Manufacturers for on-job training							1	
9	Entry-level salaries: Improve					2			
10	Engineering Bursaries: More				3				
11	Create fascination about engineering	5							
12	Incentivise Maths and Science teachers	1							
13	Employee Satisfaction: Use of Questionnaires								1
14	Exercise Equal Opportunity for bursaries (equity target should be secondary to merit cases)				4				
15	Image of Engineering: Improved	1							
16	Systems Engineering Knowledge	1						1	

⁴⁸ This tabulation is provided as a means to summarise the interviewees responses and it is not meant to form part of a quantitative analysis.

#	Intervention	Birth	Borrow	Bridge	Bind	Boost	Buy	Build	Other
17	Vacation Work	1							
18	Communications, Report Writing and Presentation Skills	1						1	
19	Bursar Information Sharing Sessions				2				
20	University Partnerships: Improvement in terms of Chairs & Faculties.	2							
21	Public knowledge of Eskom's operations: improve	2							
22	School Bursaries	1							
23	Sponsoring of third and fourth year projects	1							
24	Develop own talent					2			
25	Eskom University as an open university (not only Eskom Requirements)							4	
26	Engineering Training: Improvement to meet ECSA requirement							2	
27	Mid-career engineers: more needed					1			
28	Development and Enforcement of Engineering Processes								3
29	Gap between Academic Studies and Workplace: Needs to be closed	1							
30	Attract and Utilise more women (but not blindly)	1							
31	Expectation of Engineering as a career: needs management	2							
32	Roles for bursars: Define before getting into Eskom	2							
33	Market Engineering and Eskom at schools using Engineers	1							
34	Promote engineering more holistically (not only maths and science)	1							

#	Intervention	Birth	Borrow	Bridge	Bind	Boost	Buy	Build	Other
35	Job re-assignment on request			1					
36	China and India to supplement						2		
37	Utilise Eskom Convention Center for more engineering training							1	
38	Utilise engineering personnel in positions to utilise the talents effectively								4
39	Practical skills: Develop							1	
40	Advertise in All Mediums (including television) and use all Languages	1							
41	Training must initiate conversation							1	
42	Define training well when partnering with other companies							1	
43	Passion for Maths and Science: Create	2							
44	Financial Aid: Not only bursary, must include some form of family support (loans)				1				
45	Image of Eskom: A caring company	1							
46	Clear Picture of Engineering at Grade 8. Perceive as being "cool" (desirable).	2							
47	Motivate school children	1							
48	Provide Infrastructure for Studying (Libraries)	1							
49	Train and Test							1	
50	Relax Criteria to allow talent to develop (not all leaders have qualifications when starting off)	1							
51	Masters Programme for Enterprises Division (Technical)							1	
52	Perception of Engineering as male-dominated: Change								1
53	Recruitment Duration: shorten from 2 months to 2 weeks								1

#	Intervention	Birth	Borrow	Bridge	Bind	Boost	Buy	Build	Other
54	Secondary Schools Students: Focus on them	1							
55	Define Bursar Requirements per engineering discipline				2				
56	Career counselling at Schools: give Direction	1							
57	Utilise South African Talent				1				
58	Partnership: Skills Swop		1						
59	Foreigners with primary role of training and with limited time contracts						1		
60	Engineer Job Profiles: need to become more generic in order to pull-in external engineers						1		
61	Perform skills needs analysis(i.e. level of skill), not only man power plan								1
62	Perform Induction in a welcoming way								1
63	Retain the skills we have								1
64	Overseas training must be stepped up					1			
65	Delivery of training i.e. improved use of e-learning.							1	
66	Dedicated Instructors							1	
67	Bolstering our national academic support	1							
68	R3,5 billion SETA skill development fund should be utilised to bolster the upfront feedstock	1							
Total		39	1	1	14	6	4	26	15

Table 16 Categorisation of the alternative interventions according to Eskom's 7-Bs

The categorisation presented in Table 16 is summarised in a pie chart in Figure 22. It is significant that out of the Eskom's 7-Bs resourcing strategy, the interviewees suggested alternatives that supported the Birth and Build elements most strongly. Whilst the Bind

element was a distant fourth, preceded by interventions that fall outside of Eskom’s 7-Bs resourcing strategy (Labelled ‘Other’). In addition, it is significant to note that the most suggested alternatives form part of medium to long term elements of the 7-Bs resourcing strategy.

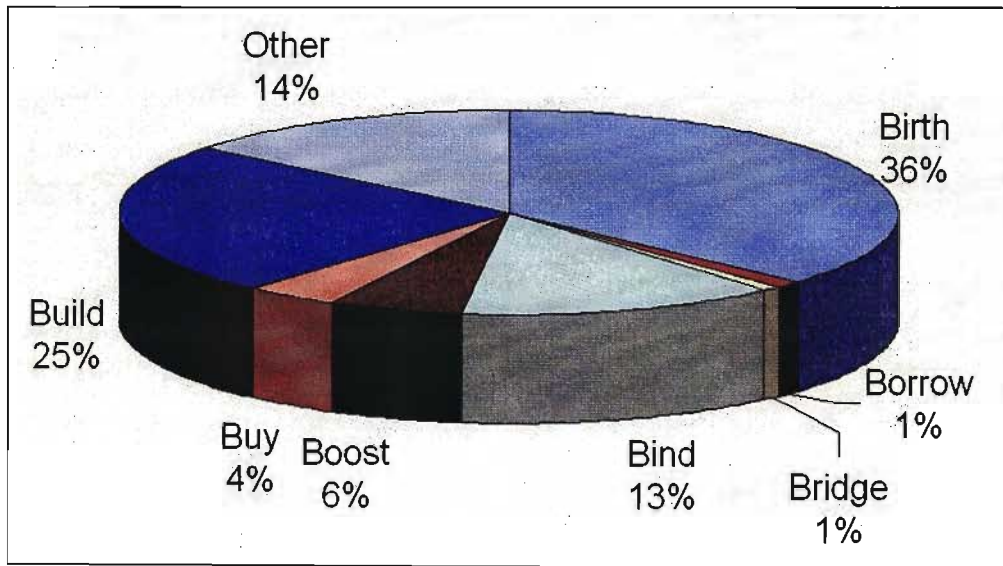


Figure 22 Summary of the categorisation of alternative interventions

Of the interventions labelled: *Other*, the 2 most supported interventions was to *Utilise engineering personnel in positions to utilise the talents effectively* and *Development and Enforcement of Engineering Processes*.

4.3 UPDATED SYSTEMS DYNAMICS MODEL AFTER INTERVIEWS

4.3.1 UPDATED SYSTEMS DYNAMICS MODEL

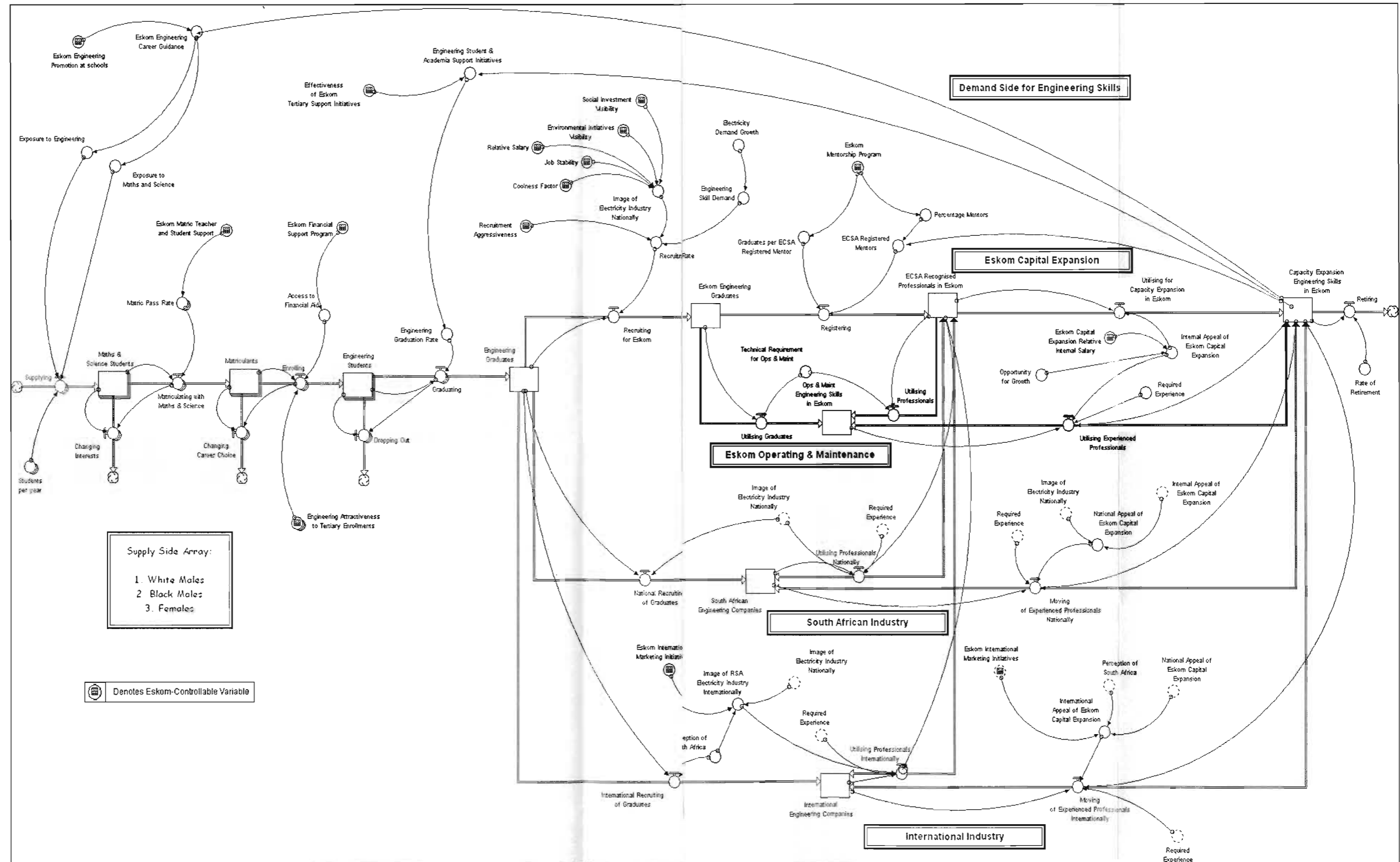


Figure 23 Updated Systems Dynamics Model depicting the Engineering skills in Eskom

The model presented in Figure 23 is an update of the draft model presented in Figure 15 (page 4) and represents the new understanding gained from the interview process. The author of this dissertation has chosen to represent the three supply feedstocks (White males, Black males and females) as an array. This arrangement de-cluttered the systems dynamics model to allow for representation of the actions and feedbacks that Eskom could explore as means to alleviate the shortage of engineering skills.

Furthermore, the following additions were made to the model:

1. Promotion of engineering at school level by Eskom
2. Matric teacher and student support by Eskom
3. Financial support to engineering students by Eskom
4. Promoting the take up of engineering tertiary education by Eskom
5. Eskom Mentorship Programme
6. International marketing initiatives by Eskom

A full listing of the equations for the updated systems dynamics model presented in Figure 23, is provided in Appendix 2: Details of Systems Dynamics Models. In essence, none of the equations were altered, apart from those that were needed to accommodate the above additions.

Finally, the influence on matriculants to choose careers in engineering just before enrolling in tertiary education institutes is depicted as *Engineering Attractiveness to Tertiary Enrollments (White Male, Black Male, Female)*.

4.3.2 ANALYSIS OF UPDATED SYSTEMS DYNAMICS MODEL

The Behaviour over Time (BoT) graph depicted in Figure 24 is presented as the Base Case for the testing of interventions that could alleviate the engineering skills problem in Eskom for its capacity expansion programme. It must be noted that the discussion presented for Figure 16: Engineering Skills in Eskom for the Capital Expansion Programme on page 4 is still relevant for this model (albeit with changes in values).

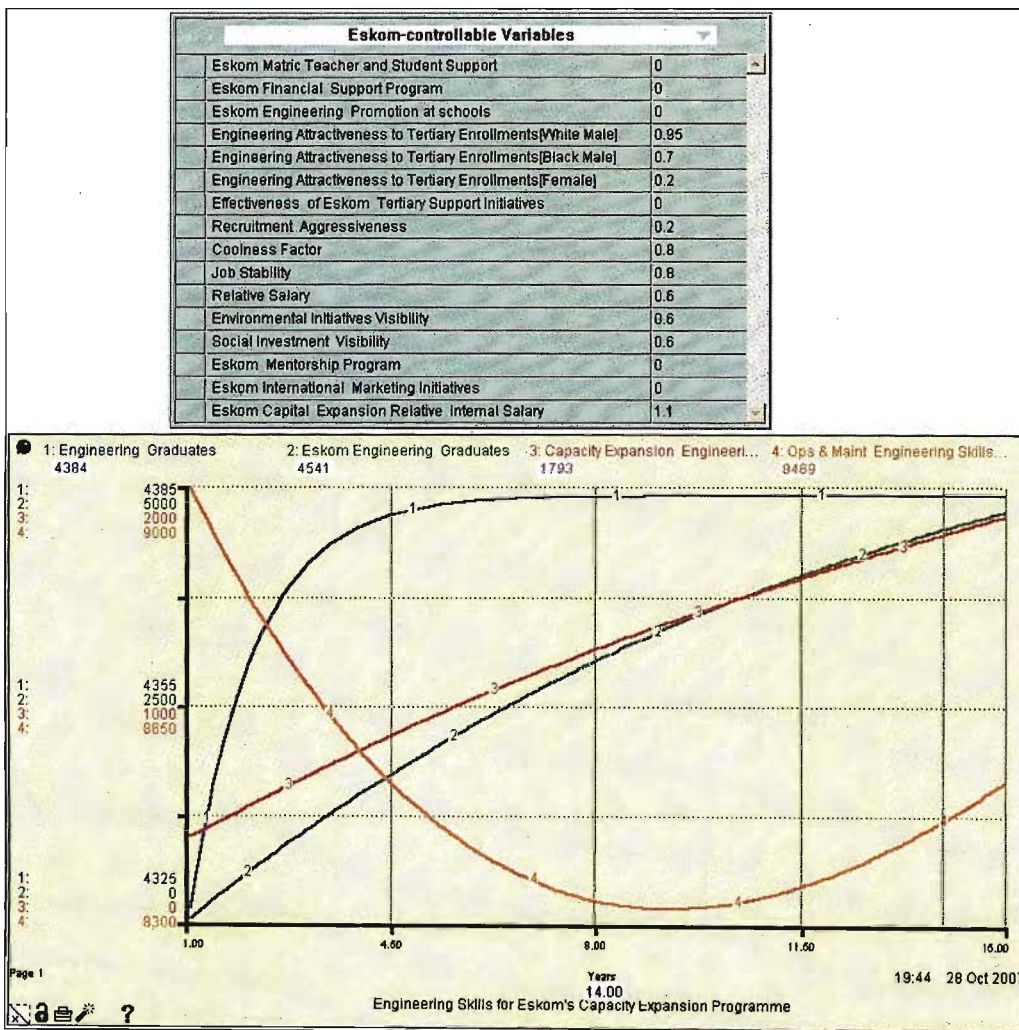


Figure 24 Updated Systems Dynamics Model: Base Case

The following summary of the discussion presented on page 4 is provided:

1. The number of engineering personnel available for Eskom’s Capital Expansion Programme will double from the now 400 people to 800 people in ~3 years i.e. by calendar year 2011.

2. The number of graduates in South Africa and Eskom builds steadily over the years. However, in both cases, it is the author's opinion that these graduates should not be growing at this rate, since as soon as these graduates get produced, they should be utilised in industry. This indicates to the author of this dissertation that industry is not absorbing available entry-level engineering skills. Further to this, there is a physical limit on the number of graduates that can be produced by the tertiary education institutes due to their own capacity limitations.
3. The skills within the Eskom's operational and maintenance domain is utilised in the capacity expansion effort. Eskom's operational and maintenance engineering skills diminishes until at such time that the graduates replenish and then surpass this loss. It must be noted that this updated model still does not take into consideration the moratorium placed on the utilisation of Eskom Generation skills for the capacity expansion effort.

In addition to the EED resources, Clive Le Roux stated the requirement for 2500 engineering staff⁴⁹ for the nuclear (build) programme by 2020⁵⁰. Using this figure together with the 800 EED resources required by 2020, this yields a figure of 3300 that is needed by 2020. Figure 24 reveals that Eskom will have just over half (~55% = 1800) of the required skills if no other additional interventions are undertaken by 2020.

In order to establish the intervention(s) that Eskom should undertake to alleviate the predicted shortage of engineering skills for the capital expansion programme, the author of this dissertation performed a sensitivity analysis with the Eskom-controlled variables described in Figure 24. The first variable that was investigated was the Eskom Mentorship Programme.

With a 1% increase in the Eskom Mentorship Programme, Figure 25, this resulted in an additional 100 engineering staff (= ~1900) by 2020. This is due to additional Eskom engineering graduates per mentor as well as additional mentors being available. With a 10% increase in the Eskom Mentorship Programme, Figure 26, this resulted in ~3400 engineering staff by 2020. It must be noted that neither of these calculations considered the issue of not having sufficient nuclear engineering mentors to start off with.

⁴⁹ This figure excludes the 3200 power station operating & maintenance staff and 1000 project management and related resources. It is based on the localisation of the nuclear build programme.

⁵⁰ This corresponds to year 14 of the BoT graph in Figure 24.

In addition, it can be noted that the number of Eskom engineering graduates drop-off as they get utilised in the capacity expansion programme. No effect was observed on the number of unutilised engineering graduates (in South Africa). Furthermore, a peculiarity was observed in the number of Operations and Maintenance skills, since the number of engineering skills in this domain continues to drop-off since the number of graduates entering the operating and maintaining domain is insufficient to replenish that lost to the capacity expansion domain. Therefore, the author suggests that the decision to place a moratorium on the transfer of skills from the operating and maintaining domain to the capacity expansion programme was a necessary decision.

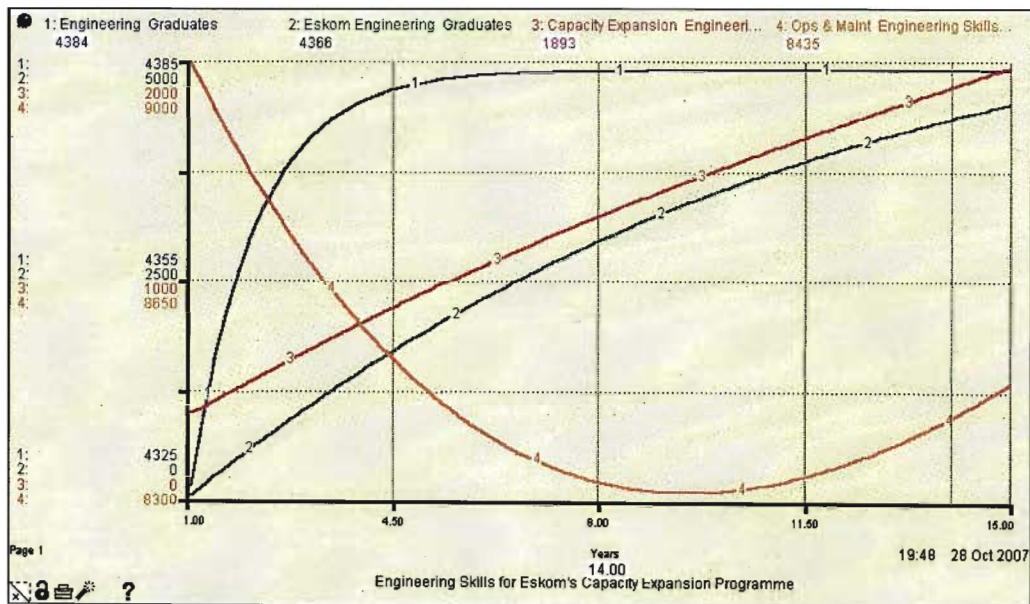


Figure 25 Updated Systems Dynamics Model: Mentorship Programme = +1%

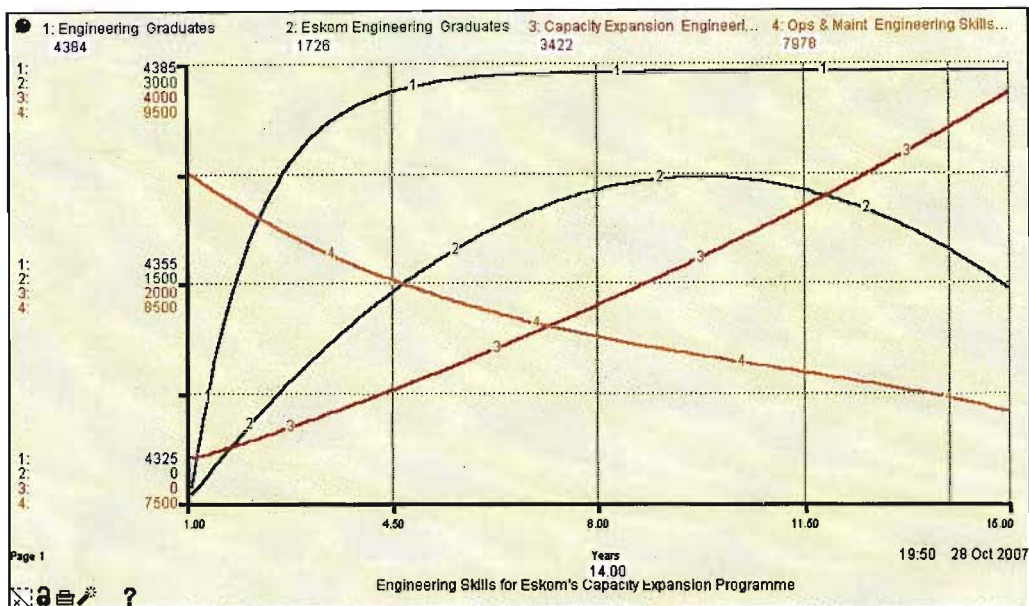


Figure 26 Updated Systems Dynamics Model: Mentorship Programme = +10%

Table 17 summarises the results on the analysis for all the other Eskom-controlled variables and the associated BoT graphs for each of these scenarios are provided in Appendix 3: Analysis of Updated Systems Dynamics Model.

#	Variable	% Change	Additional Engineering Staff ⁵¹	Normalised
1	Eskom Matric Teacher and Student Support	+20%	+39	2
2	Eskom Financial Support Programme	+20%	+38	2
3	Eskom Engineering Promotion at Schools	+20 %	+ 106	5
4	Engineering Attractiveness to Tertiary Enrollments[White Male] ⁵²	+5 %	0	0
5	Engineering Attractiveness to Tertiary Enrollments[Black Male]	+20 %	+21	1
6	Engineering Attractiveness to Tertiary Enrollments[Female]	+20 %	+28	1
7	Effectiveness of Eskom Tertiary Support Initiatives	+10 %	+156	16
8	Recruitment Aggressiveness	+10 %	+59	6
9	Multiple Variables taken individually ⁵³	+10 %	+36	4
10	Eskom International Marketing Initiatives ⁵⁴	+75 %	+498	7
11	Eskom Capital Expansion Relative Internal Salary ⁵⁵	+10 %	+796	8
12	Mentorship Programme	+10 %	+1629	163

Table 17 Summary of Analysis of changes to Eskom-controllable variables

Of significance, it must be noted that the variables that effect the number of engineering staff available for Eskom's capacity expansion programme the most, are the mentorship programme and Tertiary support initiatives. Note that although mentorship is a critical variable, there will be slowing actions, as described by the system archetypes discussed in

⁵¹ Additional Engineering Staff for Capacity Expansion for year 2020 (versus Base Case = 1793 engineering staff).

⁵² The white male feedstock is modelled as almost fully exploited (95%).

⁵³ The Coolness Factor, Job Stability, Relative Salary, Environmental Initiatives Visibility and Social Investment Visibility were increased (individually) by 10% and all had the same effect.

⁵⁴ The International marketing initiatives had to be increased significantly before any effect could be observed. This is due to the need to counter the negative perception of the electricity industry nationally and internationally.

⁵⁵ Increases in the Relative Internal Salary has profound negative consequences for the O&M part of Eskom.

section 4.1.4, to the value that mentorship can add to the system e.g. the mentorship programme could overburden the existing engineers.

In addition, Figure 31 and Figure 32 both show that increases in the number of the under-represented groups i.e. females and black males through marketing initiatives, will have a significant effect on the number of engineering graduates. Finally, Figure 33 shows that effort placed on academia and student support will significantly increase the engineering graduate output (more so than the increase in females and black males due to improved marketing initiatives).

CHAPTER 5 : CONCLUSIONS & RECOMMENDATIONS

Although Eskom has undertaken a number of initiatives underpinned by its resourcing strategy titled 7-Bs to address the engineering skills shortage for its capital expansion programme, the literature review has identified that a shortage of engineering skills still persists. This was also identified during the interview sessions. Therefore, in order to meet the near future requirements, additional focussed effort is required.

As a means of transferring skills to the younger work force, Lave *et al* (2007) specifically supported the use of retirees as mentors. In addition, the results of interviews and systems dynamics modelling suggested that there needs to be a core focus on mentorship and some of the interviewees also suggested that retirees be utilised as dedicated instructors/mentors.

Furthermore, the literature survey showed that there needs to be more collaboration between industry and academia to foster more industrially relevant engineering skills, Ferguson *et al* (2005). In support of this, the interview sessions revealed that effort needs to be placed on adequately specifying the resource requirements of Eskom's power generation capacity expansion programme i.e. plans in terms of numbers of people, qualifications and skill level are required. This will provide academia with a better understanding of industry's (including Eskom's) requirements.

The literature demonstrated commonality on the concepts of engineering skill. Furthermore, there was agreement in the literature on what should be the curriculum used to train engineers. In addition, literature and interviewees also had consensus when expressing that engineers currently do not have all the core skills necessary to perform the work when they exit the tertiary education institutes. The core skills that are lacking include the ability to perform problem solving (using a defined problem solving methodology), ability to communicate results and the lack of use of Systems Thinking/Engineering concepts.

Furthermore the capacity of the education sector in South Africa has been shown, by both the literature survey and the systems dynamics model, to introduce a constraint in the number of engineers that can produced. The literature survey confirmed the need for stronger collaboration between industry and academia. In addition, the interviewees suggested the sponsoring of "Chairs" by industry in the education institutions as one of the means to achieve this stronger collaboration.

Eskom has a significant bursary programme and a generally positive perception of this bursary programme was held by the interviewees. However, the interviewees also stated that

it could be better organised in terms of closer interaction between Eskom and with current and prospective bursars.

The literature review also attributed, in part, certain inefficiencies to inherent SOEs' inefficiencies as stated by the Department of Public Enterprises (2006). This view was supported by some interviewees expressing the view that Eskom is not utilising the engineering skills in the right positions e.g. utilising an engineer (mainly trained to do conceptual work) in a physical environment at site, whilst at the same time, also utilising technologists to do solely conceptual work (whereas they have been trained for a mix of conceptual and detailed work).

Although literature that was reviewed, Reder (2006), suggested that outsourcing could be used as a means in alleviating the engineering skills shortage, the interview sessions revealed that interviewees suggested that outsourcing of engineering work and importing of engineering skill should be pursued as a last resort.

From the literature review, Lave *et al* (2007) supported the interviewees' suggestion that having documented engineering processes would assist in alleviating the engineering skill shortage (due to being able to more easily pass the knowledge onto new recruits of how to engineer a power generation asset).

Summers & McCulley (2006), Pyke *et al* (2006) and Lave *et al* (2007) all state that the engineering discipline needs to market an improved image to the public. In addition, emphasis must be placed on the under-represented groups i.e. females and black males, being attracted into the engineering profession. This statement was re-iterated by some of the interviewees.

Additionally, one of the major concerns highlighted in the literature was the issue of not being able to retain engineering talent in the engineering profession both locally and internationally due to loss to other professions e.g. project management and to other companies. Some interviewees mentioned the need for Eskom to investigate and implement more effective employee retention strategies.

The final conclusion drawn was that the DoE and ECSA were identified as points of leverage when using the multiple cause diagram. This shows that the entities that have the most influence lie outside of Eskom's direct control.

There are reports that suggest that there is a correlation between a country's skills base (not only engineering) and economic prosperity as described by Leitch (2006) and Hawley & Raath (2002). Therefore, skills shortage is a significant problem which requires substantial effort to understand and provide effective solutions.

Furthermore, Eskom and South Africa's situation with regards to engineering skills shortage does not appear to be unique, Global Immigration Services (2006) and Department of Immigration and Multicultural Affairs (2007). Therefore the understanding gained from this study could be useful in other companies and countries. To this end, the following recommendations are offered:

In the short term, it is recommended that Eskom place emphasis on ensuring that the following are developed (and are from a sound technical basis) for the capacity expansion programme:

1. The skills level plan (i.e. competency level)
2. Manpower plan (number of people)
3. Qualification plans

This will provide Eskom with the correct focus in terms of key performance indicators for the skills output that is required.

Additionally, for the short to medium term, Eskom's main effort must be focussed towards the mentorship programme as it will have the largest positive impact on the engineering skills shortage for the capacity expansion programme. The use of retirees as dedicated instructors (and not as supplementary or replacement staff) is recommended. A further study into the possibility of overburdening the existing engineers with mentorship responsibilities and the effects thereof needs to be carried out.

In addition to this core focus on the mentorship programme, effort should be directed towards the retention of the current engineering skills complement. There are various retention mechanisms available and it is therefore recommended that Eskom should investigate the effect that these mechanisms could have on the engineering skills shortage in a further study. It is recommended that this further study makes use of systems dynamics modelling to assess the separate impact of each of the retention mechanisms.

In the medium to long term, it is recommended that Eskom provide academic support in the form of chairs at university, student support initiatives and career guidance at the school

level. In addition, effort should be allocated to attracting more of the under-represented groups into engineering i.e. women and black males. Additionally, effort should be placed in documenting the engineering processes that are followed in designing a power plant.

Finally, Eskom should collaborate more with the DoE and ECSA, since these organisations appear (from the application of Systems Thinking techniques) to be the entities with the most amount of influence. This will provide one of the enablers to ensure that the engineering skill requirements for the power generation capacity expansion programme are met.

REFERENCES

- Attewell P. (1990). 'What is Skill?', *Work and Occupations*, Volume 17, p 422-448.
- Aultman-Hall L and Holmen B (2006). 'Promoting Women As Leaders For Engineering: The Role Of Individuals, Organizations And Professional Societies', University of Connecticut, *American Society for Engineering Education*, p 3-8.
- Blenkinsop S, McCrone T, Wade P and Morris M (2006). *How Do Young People Make Choices at 14 and 16 ?*, National Foundation for Educational Research, Research Report RR773, NFER Trading Ltd, p 47-61, 125-135.
- Bourne J, Harris D and Mayadas F (2005). 'Online Engineering Education: Learning Anywhere, Anytime', Sloan Consortium, *Journal of Asynchronous Learning Networks*, Volume 9:1, p 17-37.
- Braehmer S, Kimmie Z, Greenstein R, Morake R and Seutloadi K (2000). *Youth 2000: A Study of Youth in South Africa*, Braamfontein, South Africa, Community Agency for Social Enquiry and Royal Netherlands Embassy. p 4-31.
- Braun W (2002). *The System Archetypes*,
www.uni-klu.ac.at/~gossimit/pap/sd/wb_sysarch.pdf, Accessed on 2008-11-19.
- Bussin M and Spavins R (2007). *Engaging talent: Why retention and remuneration is one of the top issues in HR*, <http://www.workinfo.com/free/downloads/222.htm>, Accessed on 2007-11-27.
- Byleveldt SA (1990). *Engineering Group: Skills Plan*, Johannesburg, Eskom.
- Caulfield CW and Maj SP (2002). 'A Case for System Dynamics', *Global Journal of Engineering Education*, Australia, Volume 6:1, p 25-34.
- Cavanna RY and Maani KE (2000). *Systems Thinking and Modelling: Understanding Change and Complexity*, Auckland, Prentice-Hall, p 56-74.
- Cheong LY and Jones RC (2005). 'Engineering and the Millennium Development Goals', USA, *American Society for Engineering Education*, p 1 –11.
- Chiu B and Lewis M (2006). *Reforming China's State-Owned Enterprises*, Cheltenham, Edward Elgar Publishing, p 81.
- Christy AD and Lima M (2005). 'The use of student portfolios to encourage industrial ties in undergraduate engineering education', Ohio State University / Louisiana State University, *American Society for Engineering Education*, p 1.
- Cilliers F (2006). 'Towards a Systems Psychodynamic understanding of consulting to South African Diversity Dynamics', Pretoria, University of South Africa, p 3, 4.
- Collins (1992). *Collins Reference English Dictionary*, Great Britain, William Collins Sons and Co. Ltd.

- Cordova-Wentling RM and Camacho C (2006). 'Women Engineers: Factors and Obstacles Related to the Pursuit of a Degree in Engineering', University of Illinois-Urbana Champaign, *American Society for Engineering Education*, p 1-36.
- Crawley EF (2001). *The CDIO Syllabus: A Statement of Goals for Undergraduate Engineering Education*, Massachusetts Institute of Technology, p 3-11.
- De Cronje GJ, du Toit GS, de K Marais A (2004). *Introduction to Business Management*, Sixth Edition, Cape Town, Oxford University Press Southern Africa, p 11, 222-234.
- Department of Education (2005). *Education Statistics in South Africa at a Glance in 2004*, Republic of South Africa, Pretoria, Government Printing Works, p 22-27.
- Department of Immigration and Multicultural Affairs (2007). *Form 1121i*, Australia, Australian Government Printers.
- Department of Labour (2006). *National Scarce Skills List*, Pretoria, Government Printers. http://www.labour.gov.za/useful_docs/doc_display.jsp?id=11695, Accessed on 2007-03-22.
- Department of Minerals and Energy (1998). *White Paper on the Energy Policy of the Republic of South Africa*, Pretoria, Government Printers.
- Department of Public Enterprises (2006). *Public Enterprises: Strategic Plan*, Pretoria, Government Printers.
- Ebben K (2006). *Review of First, Break All the Rules*, North Carolina, Performa Higher Education. <http://www.performahe.com/resources/rules.shtml>, Accessed on 2007-03-31.
- Eidgahy SY and Eydgahi HY (1997). 'Engineering and the Global Marketplace: Educating "Technicians" or Problem Solvers?', Jefferson Community College and Lima Technical College, *American Society for Engineering Education*, p 3.
- Engineering Council of South Africa (1998). *University Statistics in Engineering, Graduation numbers: 1982 – 1997*, Johannesburg, ECSA, http://www.ecsa.co.za/edu/Statistics/1982-1997/1Univ_1982-1997_Grads.html, Accessed on 2007-05-14.
- Engineering Council of South Africa (2005). *Statistics on Engineering Students, 1998 - 2004*, Johannesburg, ECSA, http://www.ecsa.co.za/edu/Statistics/1998-2004/UnivTech_1998-2004_EnrolGradsStats_files/sheet001.htm, Accessed on 2007-05-14.
- Eskom (2005a). *Enabling agreement governing the relationship between CED and the line divisions within Eskom Holdings Limited*, ECN0001, Johannesburg, Eskom, p 11.
- Eskom (2005b). *HR Advance*, Nov/Dec Edition, Johannesburg, Eskom, p 14-21.
- Eskom (2005c). *Project Life Cycle Model*, ESKAGABF9, Johannesburg, Eskom.
- Eskom (2006). *Eskom Annual Report*, Johannesburg, Eskom, p 38-40, 171.

- Eskom (2007a). *Eskom Annual Report*, Johannesburg, Eskom, p 4, 9, 63-64.
- Eskom (2007b). *Eskom Careers Expo 2007*, Johannesburg, Eskom,
http://www.eskom.co.za/live/content.php?Item_ID=4595, Accessed on 2007-09-10.
- Eskom (2007c). *Briefing Note: Eskom Expo for Young Scientists*, Johannesburg, Eskom,
http://www.eskom.co.za/live/content.php?Item_ID=4204, Accessed on 2007-06-25.
- Eskom (2008). *Eskom Annual Report*, Johannesburg, Eskom, p 30, 87, 89.
- Farrell D and Grant AJ (2005). *China's looming talent shortage*, Sydney, McKinsey Global Institute, p 1 – 7.
- Ferguson CW, Ball AK, Stone W and McCrary P (2005). 'Engaging Industry in Graduate Engineering/Technology Education', Western Carolina University, *American Society for Engineering Education*, p 2.
- Gabru F (2008). *Skills crisis challenging engineers*, Mining Weekly, 25th April 2008.
http://www.miningweekly.com/article.php?a_id=130858, Accessed on 2008-08-11
- Global Immigration Services (2006). *Skills Shortage Occupations List*, London, Global Immigration Services. http://www.workpermit.com/uk/work_permit/occupations.htm, Accessed on 2007-04-02.
- Hawley R and Raath A (2002). 'Future skill requirements for UK engineers and technologists: a review of the current position', *International Journal of Technology Management*, Volume23:6, p 630 - 642
- Hoag KL (2001). *Skills Development for Engineers*, London, The Institution of Electrical Engineers, p 6-7.
- Horwitz F (2007). *Retention strategies critical in a global market shortage of skilled workers*, Graduate School of Business, University of Cape Town,
<http://www.gsb.uct.ac.za/newsletter/v2/Story.asp?intArticleID=1591>, Accessed on 2007-11-27.
- Huitt W (2004). *Bloom et al.'s taxonomy of the cognitive domain*, Educational Psychology Interactive, Valdosta, Valdosta State University,
<http://chiron.valdosta.edu/whuitt/col/cogsys/bloom.html>, Accessed on 2007-07-27.
- Human Science Research Council (2004). *Factsheet 8 : Is there a shortage of engineers in South Africa?*, HSRC, <http://www.hsrc.ac.za/Factsheet-10.phtml>, Accessed on 2008-03-24.
- Ingalsbe D and Godbey J (2005). 'Project-Oriented Capstone Course: Integrating Curriculum Assessment Utilizing Industry Partner and Student Input', Jacksonville State University, *American Society for Engineering Education*, p 1.
- International Monetary Fund (2007). *World Economic Outlook Database*,
<http://www.imf.org/external/pubs/ft/weo/2007/02/weodata/weorept.aspx?pr.x=86&pr.y=9&sy=1986&ey=1986&scsm=1&ssd=1&sort=country&ds=.&br=1&c=512%2C94>

- [1%2C914%2C446%2C612%2C666%2C614%2C668%2C311%2C672%2C213%2C946%2C911%2C137%2C193%2C962%2C122%2C674%2C912%2C676](#), Accessed on 2008-02-24.
- ISEE Systems (2004). *ithink and STELLA Technical Documentation*, , Lebanon, ISEE Systems.
- Islam R (2006). 'Recruitment In Engineering And Technology Programmes Integrating Home Schoolers, Women And International Students', Northwestern State University, *American Society for Engineering Education*, p 2-8.
- Jahan K, Keil ZO, Hartman H and Choudhury JR (1998). 'Women in Engineering in Bangladesh and the USA: A Comparative Study', Rowan University / Bangladesh University of Engineering and Technology, *American Society for Engineering Education*, p 4.
- Keen PA (1996). 'Undergraduate Engineering Skill Preparedness', Stevens Institute of Technology, *American Society for Engineering Education*, p 1.
- Kolb DA (1984). *Experiential Learning: Experience as the source of learning and development*, Chapter 2, Englewood Cliffs, New Jersey, Prentice –Hall, p 20-38.
- Krumme G (2005). *Major Categories in the Taxonomy of Educational Objectives*, The Learning Web, Seattle, University of Washington, <http://faculty.washington.edu/krumme/guides/bloom.html>, Accessed on 2007-07-27.
- Lane A (2000). *Systems Thinking And Practice: A Primer*, The Open University, ISBN 0 7492 8403 X, Milton Keynes, United Kingdom, p 7.
- Lave LB, Ashworth M and Gellings C (2007). 'The Aging Workforce: Electricity Industry Challenges and Solutions', *The Electricity Journal*, Volume 20:2, March 2007, p 71-80.
- Lawless A (2006). *Engineering Institutes look at the skills shortage that threatens to affect the economic growth of South Africa*, Johannesburg, South African Institution of Electrical Engineers. <http://www.saiee.org.za/content.php?pageID=53andnewsID=33#>, Accessed on 2006-09-28.
- Leitch (2006). *Prosperity for all in the global economy – world class skills*, HM Treasury, UK, UK Government Printers.
- Letlape M (2007). *Eskom's Resourcing Approach*, People Dynamics, October Edition, Johannesburg, Institute of People Management, p 12-13.
- Lünsche S (2006). *Looking for High Level Skills*, Johannesburg, Financial Mail. <http://free.financialmail.co.za/report06/eskom06/feskom.htm>, Accessed on 2007-04-02.
- Microsoft (1999). *Encarta® Pocket Dictionary*, USA, Microsoft Corporation.

- Mlambo-Ngcuka P (2006). *Joint Initiative for Priority Skills Acquisition*, South Africa, Skills Portal. <http://www.skillsportal.co.za/asgisa/jipsa/140520.htm>
Accessed on 2006-09-02.
- Molewa P (2007). *GARP Project*, Johannesburg, Eskom.
<http://infonet.eskom.co.za/home.asp?pid=9689>, Accessed on 2006-07-12.
- Moodley B (2006a). *MCom Term Paper: Shortage of Engineering Skills in South Africa*, Johannesburg, Eskom, p 5-8.
- Moodley B (2006b). *Systems Dynamics Modelling: Impact of Skills Shortage in South Africa on Economy*, Johannesburg, Eskom, p 3-6.
- Morsi R (2005). 'Girls In Science, Engineering, and Technology (GISET)', Norfolk State University, *American Society for Engineering Education*, p 1-8.
- Motileng BB (2004). *Affirmative Action: The experience of people in middle management positions*, Faculty of Humanities, University of Pretoria, p 24.
- Mphelo M (2004). *Development and Mentorship of New Graduates*, Johannesburg, Eskom, p 4.
- O' Connor D and Lunati MR (1999). *Economic Opening and the Demand for Skills in Developing Countries: A Review of Theory and Evidence*, OECD Development Centre, OECD Publishing, p 7, 16.
- Officer RR (1999). 'Privatization of Public Assets', Melbourne Business School, University of Melbourne, p 1-22.
- Ok W and Tergeist P (2003). *Improving Workers' Skills: Analytical Evidence and the Role of the Social Partners*, OECD Social Employment and Migration Working Papers, No. 10, OECD Publishing, p 3-4.
- Oregon State University (2007). *Pedagogy*, School of Chemical, Biological and Environmental Engineering, <http://cbee.oregonstate.edu/education/Pedagogy/>, Accessed on 2008-02-24.
- Organisation for Economic Co-operation and Development (2005). *Statistics Canada and OECD 2005*, Chapter 5: Skills and the Labour Force, OECD Publishing, p 107.
- Organisation for Economic Co-operation and Development (2006a). *Managing Migration – Are Quotas and Numerical Limits the Solution ?*, International Migration Outlook, OECD Publishing, p 123-125.
- Organisation for Economic Co-operation and Development (2006b). *OECD Economic Surveys: Brazil*, Chapter 4: Improving labour utilisation, OECD Publishing, p 119-120.
- Pandor N (2008). *Co-ordination of skills development*, Department of Education, <http://www.info.gov.za/speeches/2008/08021213451001.html>, Accessed on 2008-02-24.

- Patrick C and Crebert G (2004). *A Whole New Ball-Game: Generic Skills In An Engineering School – Are They Taught, Or Merely Caught?*, Australia, Griffith University, p 1.
- Pauw K, Borat H, Goga S, Ncube L and van der Westhuizen C (2006). *Graduate Unemployment in the Context of Skills Shortages, Education and Training: Findings from a Firm Survey*, Development Policy Research Unit, Cape Town, University of Cape Town.
- Perkins P, Fedderke J and Luiz J (2005). 'An Analysis of Economic Infrastructure Investment in South Africa', *South African Journal of Economics*, Volume 73:2, p 211-228.
- Pyke P, Lete A, Budinoff L, Hampikian C, Luque M, Schrader C and Taylor M (2006). 'Where The Girls Are: Applying An Integrated Marketing Approach To Attract Girls Into Engineering Programmes'; Chicago, *ASCE Annual Conference and Exposition: Excellence in Education*, p 4-9.
- Reder WK (2006). *The Technical Talent Challenge*, IEEE Power and Energy Magazine, January/February Edition, IEEE, p 32-39.
- Reding V (2008). *Women in ICT : Status and the way ahead*, Information Society and Media, European Commission, p 11.
- Republic of South Africa (1998). *Skills Development Act*, Pretoria, Government Printers.
- Republic of South Africa (2000). *Engineering Profession Act*, Pretoria, Government Printers.
- Republic of South Africa (2006a). *Accelerated And Shared Growth Initiative For South Africa 2006 Annual Report*, Pretoria, Government Printers.
- Republic of South Africa (2006b). *Joint Initiative on Priority Skills Acquisition*, Pretoria, Government Printers, <http://www.info.gov.za/otherdocs/2006/jipsa.pdf>, Accessed on 2007-03-23.
- Ramlall S (2003). 'Organizational Application: Managing Employee Retention as a Strategy for Increasing Organizational Competitiveness', *Applied H.R.M. Research*, Volume 8:2, p 63-72.
- Rigby M and Sanchis E (2006). *The concept of skill and its social construction*, London, London South Bank University.
- Robertson J and Weihmeir J (2005). 'Managing the Industry-Academic Interface', Arizona State University and Freescale Semiconductor, *American Society for Engineering Education*, p 1-3.
- SAinfo (2007). *SA 2010 confidence climbs*, International Marketing Council of South Africa, Big Media Publishers (Pty) Limited, www.southafrica.info/2010/barometer-nov2007.htm, Accessed on 2008-03-22.
- Seat E (1998). 'Women Engineers: Preparing Them For The Workplace', University of Tennessee, *American Society for Engineering Education*, p 7-8.

- Siller JT and Gearold RJ (2004). 'Constituent Influences on Engineering Curricula', Colorado State University, *American Society for Engineering Education*, p 2-9.
- Solidariteit (2008). *The Electricity Congress Held On 24 April 2008*, Pretoria, Institute for Constitutional and Labour Law Studies, Solidariteit, http://www.solidariteitinstituut.co.za/docs/opsomming_elektrisiteitskongres.pdf, Accessed on 2008-12-09.
- Smith R, Roodt J, Primo N. Evans N and James T (2006). *Women in the Information and Communication Technology Sector in South Africa*, Pretoria, Meraka Institute, CSIR, p 2.
- Starr RM (2004). *What does an engineer do?*, Lorain County, Central Operation of Resources for Educators, NASA, http://ksnn.larc.nasa.gov/k2/m_whatEngineer.html, Accessed on 2007-08-26.
- Sterman JD (2000). *Business Dynamics: Systems Thinking and Modelling for a Complex World*, Irwin, McGraw-Hill, p 8-25.
- Sterman JD (2001). 'System Dynamics Modelling: Tools for Learning in a Complex World', *California Management Review*, California, Volume 43:4, p 3-39.
- Summers R and McCulley J (2006). 'Applying Marketing Principles To Attracting And Retaining Engineering Students', Chicago, *ASEE Annual Conference and Exposition: Excellence in Education*, p 2-4.
- Thakali T (2008). *Eskom woes drive engineers to emigration*, The Cape Argus, <http://www.capeargus.co.za/index.php?fArticleId=4245611>, Accessed on 2008-03-24
- Thomas S (2004). *Electricity liberalisation: The beginning of the end*, Public Services International, World Energy Council Congress, p 6.
- Trevelyan JP and Tilli S (2003). *Observations from a Study of Professional Engineering in Australia and Pakistan*, Perth, School of Mechanical Engineering, The University of Western Australia, p 4.
- Trevelyan JP (2006). *Definition of Engineering Roles*, Revision 3.2, Perth, School of Mechanical Engineering, The University of Western Australia.
- Tyers C and Sinclair A (2005). *Intermediate Impacts of Advice and Guidance*, Research Report RR638, Institute for Employment Studies, p 34.
- Ulrich D (1998). 'A New Mandate for Human Resources', *Harvard Business Review*, January/February, pp. 124-134.
- Ulrich D and Smallwood N (2004). 'Capitalizing on Capabilities', *Harvard Business Review*, June, pp. 119-127.
- University of KwaZulu-Natal (2007). *Innovation Park*, ukzndaba, Volume 4:1, Durban, University of KwaZulu-Natal, p 1.

Van Harte M (2006). *International Comparative Higher Education Finance and Accessibility Project: South Africa*, Education Policy Unit, University of the Western Cape, South Africa,

http://www.gse.buffalo.edu/org/IntHigherEdFinance//region_africa_SAfrica.html,

Accessed on 2007-10-14.

Vukanikids (2005). *ICT Skills needs*, Pretoria, DTI and ISETT SETA, p 26, 52.

Zastavker YV, Ong M, and Page L (2006). 'Women in Engineering: Exploring the Effects of Project-Based Learning in a First-Year Undergraduate Engineering Programme', San Diego, *36th ASEE/IEEE Frontiers in Education Conference*, p 1-4.

APPENDIX 1: LIST OF QUESTIONS PER INTERVIEWEE

#	Interviewee	Questions
1	Senior Manager: ex- Enterprises Engineering Department (EED) and Nuclear Programme Department	From your perspective, how large is the engineering skills shortage in Eskom ? What manifestation of the engineering skills shortage in Eskom do you see in the work we do ? What interaction do you have with Eskom Human Resources (HR) and Training in terms of engineering skills shortage in Eskom ? What should we be doing and not be doing to alleviate engineering skills shortage in Eskom ?
2	Senior Manager: Eskom Human Resources	From your perspective, how large is the engineering skills shortage in Eskom ? What is Eskom's current strategy to alleviate this shortage ? What recruitment strategies are in place for engineering skills ? What developmental strategies are in place for engineering skills? What retention strategies are in place for engineering skills ? What are the key performance indicators (KPIs) for your area ? Which of these KPIs are directly related to the engineering skills shortage issue ? What interaction do you have with Enterprises Engineering Department (EED) and Training in terms of engineering skills shortage in Eskom ?
3	Leadership and Professional Development Manager (located within the Human Resources department)	From your perspective, how large is the engineering skills shortage in Eskom ? What is Eskom's developmental strategy for engineering skills ? What are the key performance indicators (KPIs) for your area ? Which of these KPIs are directly related to the engineering skills shortage issue ? What interaction do you have with Enterprises Engineering Department (EED) and Human Resources (HR) in terms of engineering skills shortage in Eskom ?

#	Interviewee	Questions
4	Discipline Engineering Managers in EED	From your perspective, how large is the engineering skills shortage in Eskom ? What manifestation of the engineering skills shortage in Eskom do you see in the work we do ? What interaction do you have with Eskom Human Resources (HR) and Training in terms of engineering skills shortage in Eskom ? What should we be doing and not be doing to alleviate engineering skills shortage in Eskom ?
5	Senior Engineering Staff (Chief & Senior Engineers and Senior Engineering Technologists)	From your perspective, how large is the engineering skills shortage in Eskom ? What manifestation of the engineering skills shortage in Eskom do you see in the work we do ? What should we be doing and not be doing to alleviate engineering skills shortage in Eskom ? What skills do the junior staff lack ? How can these skills be developed ?
6	Engineers and Engineering Technologists	From your perspective, how large is the engineering skills shortage in Eskom ? What manifestation of the engineering skills shortage in Eskom do you see in the work we do ? What should we be doing and not be doing to alleviate engineering skills shortage in Eskom ?
7	Graduates in Training	Do you know what is expected of you at work? Do you have the right materials and equipment you need to do your work right? Do you have the opportunity to do what you do best every day? Is there someone at work who encourages your development? Have you had adequate training for the job ? What should we be doing and not be doing to alleviate engineering skills shortage in Eskom ?

Table 18 List of questions per interviewee

APPENDIX 2: DETAILS OF SYSTEMS DYNAMICS MODELS

This appendix provides the detail of the equations and initial values of stocks, flows and converter elements of the draft and updated systems dynamics models.

DETAILS OF DRAFT SYSTEMS DYNAMICS MODEL**STOCKS & FLOWS OF DRAFT SYSTEMS DYNAMICS MODEL****BLACK MALE MATHS AND SCIENCE STUDENTS****Equation:**

Black Male Maths & Science Students(t) = Black Male Maths & Science Students(t - dt) + (Supplying Black Males - Black Males Matriculating with Maths & Science - Black Males Changing Interests) * dt

Inflows:

Supplying Black Males = (Exposure to Engineering + Exposure to Maths and Science) * Black Males per Year

Outflows:

Black Males Matriculating with Maths & Science = Black Male Maths & Science Students * Matric Pass Rate

Black Males Changing Interests = Black Male Maths & Science Students - Black Males Matriculating with Maths & Science

BLACK MALE ENGINEERING STUDENTS

Equation:

Black Male Engineering Students(t) = Black Male Engineering Students(t - dt) + (Enrolling Black Males - Graduating Black Males - Black Males Dropping Out) * dt

Inflows:

Enrolling Black Males = Black Male Matriculants * Access to Financial Aid * Marketing to Black Males

Outflows:

Graduating Black Males = Black Male Engineering Students * Engineering Graduation Rate

Black Males Dropping Out = Black Male Engineering Students - Graduating Black Males

BLACK MALE MATRICULANTS

Equation:

Black Male Matriculants(t) = Black Male Matriculants(t - dt) + (Black Males Matriculating with Maths & Science - Enrolling Black Males - Black Males Changing Career Choice) * dt

Inflows:

Black Males Matriculating with Maths & Science = Black Male Maths & Science Students * Matric Pass Rate

Outflows:

Enrolling Black Males = Black Male Matriculants * Access to Financial Aid * Marketing to Black Males

Black Males Changing Career Choice = Black Male Matriculants - Enrolling Black Males

ECOSA RECOGNISED PROFESSIONALS IN ESKOM

Equation:

ECOSA Recognised Professionals in Eskom(t) = ECOSA Recognised Professionals in Eskom(t - dt) + (Registering - Utilising Professionals - Utilising Professionals Nationally - Utilising Professionals Internationally - Utilising for Capacity Expansion in Eskom) * dt

Inflows:

Registering = ECOSA Registered Mentors * Graduates per ECOSA Registered Mentor

Outflows:

Utilising Professionals = ECOSA Recognised Professionals in Eskom * Technical Requirement for Ops & Maint

Utilising Professionals Nationally = (IF(Image of Electricity Industry Nationally>1) THEN((1 - Image of Electricity Industry Nationally) * South African Engineering Companies) ELSE((1 - Image of Electricity Industry Nationally) * ECOSA Recognised Professionals in Eskom))*Required Experience

Utilising Professionals Internationally = (IF(Image of RSA Electricity Industry Internationally>1) THEN((1 - Image of RSA Electricity Industry Internationally) * International Companies utilising engineering skills) ELSE((1 - Image of RSA Electricity Industry Internationally) * ECOSA Recognised Professionals in Eskom))*Required Experience

Utilising for Capacity Expansion in Eskom = ECOSA Recognised Professionals in Eskom * Internal Appeal of Eskom Capital Expansion

ENGINEERING GRADUATES IN ESKOM

Equation:

Engineering Graduates in Eskom(t) = Engineering Graduates in Eskom(t - dt) + (Recruiting for Eskom - Registering - Utilising Graduates) * dt

Inflows:

Recruiting for Eskom = Engineering Graduates * Recruitment Rate

Outflows:

Registering = ECSA Registered Mentors * Graduates per ECSA Registered Mentor

Utilising Graduates = Technical Requirement for Ops & Maint * Engineering Graduates in Eskom

ENGINEERING SKILLS IN ESKOM FOR CAPACITY EXPANSION

Equation:

Engineering Skills in Eskom for Capacity Expansion(t) = Engineering Skills in Eskom for Capacity Expansion(t - dt) + (Utilising for Capacity Expansion in Eskom - Retiring - Moving of Experienced Professionals Internationally - Utilising Experienced Professionals - Moving of Experienced Professionals Nationally) * dt

Inflows:

Utilising for Capacity Expansion in Eskom = ECSA Recognised Professionals in Eskom * Internal Appeal of Eskom Capital Expansion

Outflows:

Retiring = Engineering Skills in Eskom for Capacity Expansion * Rate of Retirement

Moving of Experienced Professionals Internationally = (IF(International Appeal of Eskom Capital Expansion>1) THEN((1 - International Appeal of Eskom Capital Expansion) * International Companies utilising engineering skills) ELSE((1 - International Appeal of Eskom Capital Expansion) * Engineering Skills in Eskom for Capacity Expansion))*Required Experience

Utilising Experienced Professionals = (IF(Internal Appeal of Eskom Capital Expansion>1) THEN((1 - Internal Appeal of Eskom Capital Expansion) * Engineering Skills in Eskom for other uses eg operations&maint) ELSE((1 - Internal Appeal of Eskom Capital Expansion) * Engineering Skills in Eskom for Capacity Expansion))*Required Experience

Moving of Experienced Professionals Nationally = (IF(National Appeal of Eskom Capital Expansion>1) THEN((1 - National Appeal of Eskom Capital Expansion) * South African Engineering Companies) ELSE((1 - National Appeal of Eskom Capital Expansion) * Engineering Skills in Eskom for Capacity Expansion))*Required Experience

ENGINEERING SKILLS IN ESKOM FOR OTHER USES EG OPERATIONS & MAINTENANCE

Equation:

Engineering Skills in Eskom for other uses eg operations&maint(t) = Engineering Skills in Eskom for other uses eg operations&maint(t - dt) +
 (Utilising Graduates + Utilising Professionals + Utilising Experienced Professionals) * dt

Inflows / Outflows:

Utilising Graduates = Technical Requirement for Ops & Maint * Engineering Graduates in Eskom

Utilising Professionals = ECSA Recognised Professionals in Eskom * Technical Requirement for Ops & Maint

Utilising Experienced Professionals = (IF(Internal Appeal of Eskom Capital Expansion>1) THEN((1 - Internal Appeal of Eskom Capital Expansion)
 * Engineering Skills in Eskom for other uses eg operations&maint) ELSE((1 - Internal Appeal of Eskom Capital Expansion) * Engineering Skills in
 Eskom for Capacity Expansion))*Required Experience

ENGINEERING GRADUATES

Equation:

Engineering Graduates(t) = Engineering Graduates(t - dt) + (Graduating White Males + Graduating Black Males + Graduating Females - Recruiting for Eskom - Interational Recruiting of Graduates - National Recruiting of Graduates) * dt

Inflows:

Graduating White Males = White Male Engineering Students * Engineering Graduation Rate

Graduating Black Males = Black Male Engineering Students * Engineering Graduation Rate

Graduating Females = Female Engineering Students * Engineering Graduation Rate

Outflows:

Recruiting for Eskom = Engineering Graduates * Recruitment Rate

Interational Recruiting of Graduates = (1 - Perception of South Africa) * Engineering Graduates

National Recruiting of Graduates = (1 - Image of Electricity Industry Nationally) * Engineering Graduates

FEMALE ENGINEERING STUDENTS

Equation:

$$\text{Female Engineering Students}(t) = \text{Female Engineering Students}(t - dt) + (\text{Enrolling Females} - \text{Graduating Females} - \text{Female Dropping Out}) * dt$$

Inflows:

$$\text{Enrolling Females} = \text{Female Matriculants} * \text{Access to Financial Aid} * \text{Marketing to Females}$$

Outflows:

$$\text{Graduating Females} = \text{Female Engineering Students} * \text{Engineering Graduation Rate}$$

$$\text{Female Dropping Out} = \text{Female Engineering Students} - \text{Graduating Females}$$

FEMALE MATHS & SCIENCE STUDENTS

Equation:

$$\text{Female Maths \& Science Students}(t) = \text{Female Maths \& Science Students}(t - dt) + (\text{Female Supply} - \text{Females Matriculating with Maths \& Science} - \text{Females Changing Interests}) * dt$$

Inflows:

$$\text{Female Supply} = \text{Exposure to Engineering} + \text{Exposure to Maths and Science} * \text{Females per Year}$$

Outflows:

$$\text{Females Matriculating with Maths \& Science} = \text{Female Maths \& Science Students} * \text{Matric Pass Rate}$$

$$\text{Females Changing Interests} = \text{Female Maths \& Science Students} - \text{Females Matriculating with Maths \& Science}$$

FEMALE MATRICULANTS

Equation:

Female Matriculants(t) = Female Matriculants(t - dt) + (Females Matriculating with Maths & Science - Enrolling Females - Females Changing Career Choice) * dt

Inflows:

Females Matriculating with Maths & Science = Female Maths & Science Students * Matric Pass Rate

Outflows:

Enrolling Females = Female Matriculants * Access to Financial Aid * Marketing to Females

Females Changing Career Choice = Female Matriculants - Enrolling Females

INTERNATIONAL COMPANIES UTILISING ENGINEERING SKILLS

Equation:

International Companies utilising engineering skills(t) = International Companies utilising engineering skills(t - dt) + (Utilising Professionals Internationally + Moving of Experienced Professionals Internationally + Interational Recruiting of Graduates) * dt

Inflows / Outflows:

Utilising Professionals Internationally = (IF(Image of RSA Electricity Industry Internationally>1) THEN((1 - Image of RSA Electricity Industry Internationally) * International Companies utilising engineering skills) ELSE((1 - Image of RSA Electricity Industry Internationally) * ECSA Recognised Professionals in Eskom))*Required Experience

Moving of Experienced Professionals Internationally = (IF(International Appeal of Eskom Capital Expansion>1) THEN((1 - International Appeal of Eskom Capital Expansion) * International Companies utilising engineering skills) ELSE((1 - International Appeal of Eskom Capital Expansion) * Engineering Skills in Eskom for Capacity Expansion)))*Required Experience

Interational Recruiting of Graduates = (1 - Perception of South Africa) * Engineering Graduates

SOUTH AFRICAN ENGINEERING COMPANIES

Equation:

South African Engineering Companies(t) = South African Engineering Companies(t - dt) + (Utilising Professionals Nationally + Moving of Experienced Professionals Nationally + National Recruiting of Graduates) * dt

Inflows / Outflows:

Utilising Professionals Nationally = (IF(Image of Electricity Industry Nationally>1) THEN((1 - Image of Electricity Industry Nationally) * South African Engineering Companies) ELSE((1 - Image of Electricity Industry Nationally) * ECSA Recognised Professionals in Eskom)) * Required Experience

Moving of Experienced Professionals Nationally = (IF(National Appeal of Eskom Capital Expansion>1) THEN((1 - National Appeal of Eskom Capital Expansion) * South African Engineering Companies) ELSE((1 - National Appeal of Eskom Capital Expansion) * Engineering Skills in Eskom for Capacity Expansion)) * Required Experience

National Recruiting of Graduates = (1 - Image of Electricity Industry Nationally) * Engineering Graduates

WHITE MALE MATHS & SCIENCE STUDENTS

Equation:

White Male Maths & Science Students(t) = White Male Maths & Science Students(t - dt) + (Supplying White Males - White Males Matriculating with Maths & Science - White Males Changing Interests) * dt

Inflows:

Supplying White Males = (Exposure to Engineering + Exposure to Maths and Science) * Whites Males per Year

Outflows:

White Males Matriculating with Maths & Science = White Male Maths & Science Students * Matric Pass Rate

White Males Changing Interests = White Male Maths & Science Students - White Males Matriculating with Maths & Science

WHITE MALE MATRICULANTS

Equation:

White Male Matriculants(t) = White Male Matriculants(t - dt) + (White Males Matriculating with Maths & Science - Enrolling White Males - White Males Changing Career Choice) * dt

Inflows:

White Males Matriculating with Maths & Science = White Male Maths & Science Students * Matric Pass Rate

Outflows:

Enrolling White Males = Marketing to White Males * Access to Financial Aid * White Male Matriculants

White Males Changing Career Choice = White Male Matriculants - Enrolling White Males

WHITE MALE ENGINEERING STUDENTS

Equation:

White Male Engineering Students(t) = White Male Engineering Students(t - dt) + (Enrolling White Males - Graduating White Males - White Males Dropping Out) * dt

Inflows:

Enrolling White Males = Marketing to White Males * Access to Financial Aid * White Male Matriculants

Outflows:

Graduating White Males = White Male Engineering Students * Engineering Graduation Rate

White Males Dropping Out = White Male Engineering Students - Graduating White Males

DETAILS OF UPDATED SYSTEMS DYNAMICS MODEL

- Capacity_Expansion_Engineering_Skills_in_Eskom(t) =
 Capacity_Expansion_Engineering_Skills_in_Eskom(t- dt) +
 (Utilising_for_Capacity_Expansion_in_Eskom - Retiring -
 Moving_of_Experienced_Professionals_Internationally - Utilising_Experienced_Professionals -
 Moving_of_Experienced_Professionals_Nationally) * dt
 INIT Capacity_Expansion_Engineering_Skills_in_Eskom = 400
 INFLOWS:
 ↻ Utilising_for_Capacity_Expansion_in_Eskom =
 ECSA_Recognised_Professionals_in_Eskom*Internal_Appeal_of_Eskom_Capital_Expansion
- OUTFLOWS:
 ↻ Retiring = Capacity_Expansion_Engineering_Skills_in_Eskom*Rate_of_Retirement
 ↻ Moving_of_Experienced_Professionals_Internationally =
 (IF(International_Appeal_of_Eskom_Capital_Expansion>1)
 THEN((1-International_Appeal_of_Eskom_Capital_Expansion)*International_Engineering_C
 ompanies)
 ELSE((1-International_Appeal_of_Eskom_Capital_Expansion)*Capacity_Expansion_Engi
 neering_Skills_in_Eskom))*Required_Experience
 ↻ Utilising_Experienced_Professionals =
 (IF(Internal_Appeal_of_Eskom_Capital_Expansion>1)
 THEN((1-Internal_Appeal_of_Eskom_Capital_Expansion)*Ops_&_Maint_Engineering_Skill
 s_in_Eskom)
 ELSE((1-Internal_Appeal_of_Eskom_Capital_Expansion)*Capacity_Expansion_Engineerin
 g_Skills_in_Eskom))*Required_Experience
 ↻ Moving_of_Experienced_Professionals_Nationally =
 (IF(National_Appeal_of_Eskom_Capital_Expansion>1)
 THEN((1-National_Appeal_of_Eskom_Capital_Expansion)*South_African_Engineering_Com
 panies)
 ELSE((1-National_Appeal_of_Eskom_Capital_Expansion)*Capacity_Expansion_Engineerin
 g_Skills_in_Eskom))*Required_Experience
- ECSA_Recognised_Professionals_in_Eskom(t) = ECSA_Recognised_Professionals_in_Eskom(t-
 dt) + (Registering - Utilising_Professionals - Utilising_Professionals_Nationally -
 Utilising_Professionals_Internationally - Utilising_for_Capacity_Expansion_in_Eskom) * dt
 INIT ECSA_Recognised_Professionals_in_Eskom = 0
 INFLOWS:
 ↻ Registering = ECSA_Registered_Mentors*Graduates_per_ECSA_Registered_Mentor
- OUTFLOWS:
 ↻ Utilising_Professionals =
 ECSA_Recognised_Professionals_in_Eskom*Technical_Requirement_for_Ops_&_Maint
 ↻ Utilising_Professionals_Nationally = (IF(Image_of_Electricity_Industry_Nationally>1)
 THEN((1-Image_of_Electricity_Industry_Nationally)*South_African_Engineering_Companies)
 ELSE((1-Image_of_Electricity_Industry_Nationally)*ECSA_Recognised_Professionals_in_Es
 kom))*Required_Experience
 ↻ Utilising_Professionals_Internationally =
 (IF(Image_of_RSA_Electricity_Industry_Internationally>1)
 THEN((1-Image_of_RSA_Electricity_Industry_Internationally)*International_Engineering_Com
 panies)
 ELSE((1-Image_of_RSA_Electricity_Industry_Internationally)*ECSA_Recognised_Profession
 als_in_Eskom))*Required_Experience

- INFLOWS:
- ↻ Utilising_Professionals_Internationally =
 (IF(Image_of_RSA_Electricity_Industry_Internationally>1)
 THEN((1-Image_of_RSA_Electricity_Industry_Internationally)*International_Engineering_Companies)
 ELSE((1-Image_of_RSA_Electricity_Industry_Internationally)*ECSA_Recognised_Professionals_in_Eskom)*Required_Experience
 - ↻ Moving_of_Experienced_Professionals_Internationally =
 (IF(International_Appeal_of_Eskom_Capital_Expansion>1)
 THEN((1-International_Appeal_of_Eskom_Capital_Expansion)*International_Engineering_Companies)
 ELSE((1-International_Appeal_of_Eskom_Capital_Expansion)*Capacity_Expansion_Engineering_Skills_in_Eskom)*Required_Experience
 - ↻ International_Recruiting_of_Graduates =
 (1-Perception_of_South_Africa)*Engineering_Graduates
- Maths_&__Science_Students[White_Male](t) = Maths_&__Science_Students[White_Male](t - dt) +
 (Supplying[White_Male] - Matriculating_with__Maths_&__Science[White_Male] - Changing_Interests[White_Male]) * dt
 INIT Maths_&__Science_Students[White_Male] = Supplying[White_Male]
- Maths_&__Science_Students[Black_Male](t) = Maths_&__Science_Students[Black_Male](t - dt) +
 (Supplying[Black_Male] - Matriculating_with__Maths_&__Science[Black_Male] - Changing_Interests[Black_Male]) * dt
 INIT Maths_&__Science_Students[Black_Male] = Supplying[Black_Male]
- Maths_&__Science_Students[Female](t) = Maths_&__Science_Students[Female](t - dt) +
 (Supplying[Female] - Matriculating_with__Maths_&__Science[Female] - Changing_Interests[Female]) * dt
 INIT Maths_&__Science_Students[Female] = Supplying[Female]
- INFLOWS:
- ↻ Supplying[White_Male] =
 (Exposure_to_Engineering+Exposure_to__Maths_and_Science)*Students_per_year[White_Male]
 - ↻ Supplying[Black_Male] =
 (Exposure_to_Engineering+Exposure_to__Maths_and_Science)*Students_per_year[Black_Male]
 - ↻ Supplying[Female] =
 (Exposure_to_Engineering+Exposure_to__Maths_and_Science)*Students_per_year[Female]
- OUTFLOWS:
- ↻ Matriculating_with__Maths_&__Science[White_Male] =
 Maths_&__Science_Students[White_Male]*Matric_Pass_Rate[White_Male]
 - ↻ Matriculating_with__Maths_&__Science[Black_Male] =
 Maths_&__Science_Students[Black_Male]*Matric_Pass_Rate[Black_Male]
 - ↻ Matriculating_with__Maths_&__Science[Female] =
 Maths_&__Science_Students[Female]*Matric_Pass_Rate[Female]
 - ↻ Changing_Interests[People] =
 Maths_&__Science_Students[People]-Matriculating_with__Maths_&__Science[People]
- Matriculants[White_Male](t) = Matriculants[White_Male](t - dt) +
 (Matriculating_with__Maths_&__Science[White_Male] - Enrolling[White_Male] - Changing_Career_Choice[White_Male]) * dt
 INIT Matriculants[White_Male] = Matriculating_with__Maths_&__Science[White_Male]

- $\text{Matriculants[Black_Male]}(t) = \text{Matriculants[Black_Male]}(t - dt) + (\text{Matriculating_with_Maths_ \& _Science[Black_Male]} - \text{Enrolling[Black_Male]} - \text{Changing_Career_Choice[Black_Male]}) * dt$
 INIT $\text{Matriculants[Black_Male]} = \text{Matriculating_with_Maths_ \& _Science[Black_Male]}$
- $\text{Matriculants[Female]}(t) = \text{Matriculants[Female]}(t - dt) + (\text{Matriculating_with_Maths_ \& _Science[Female]} - \text{Enrolling[Female]} - \text{Changing_Career_Choice[Female]}) * dt$
 INIT $\text{Matriculants[Female]} = \text{Matriculating_with_Maths_ \& _Science[Female]}$
- INFLOWS:
- ↻ $\text{Matriculating_with_Maths_ \& _Science[White_Male]} = \text{Maths_ \& _Science_Students[White_Male]} * \text{Matric_Pass_Rate[White_Male]}$
 - ↻ $\text{Matriculating_with_Maths_ \& _Science[Black_Male]} = \text{Maths_ \& _Science_Students[Black_Male]} * \text{Matric_Pass_Rate[Black_Male]}$
 - ↻ $\text{Matriculating_with_Maths_ \& _Science[Female]} = \text{Maths_ \& _Science_Students[Female]} * \text{Matric_Pass_Rate[Female]}$
- OUTFLOWS:
- ↻ $\text{Enrolling[White_Male]} = \text{Engineering_Attractiveness_to_Tertiary_Enrollments[White_Male]} * \text{Access_to_Financial_Aid} * \text{Matriculants[White_Male]}$
 - ↻ $\text{Enrolling[Black_Male]} = \text{Matriculants[Black_Male]} * \text{Engineering_Attractiveness_to_Tertiary_Enrollments[Black_Male]} * \text{Access_to_Financial_Aid}$
 - ↻ $\text{Enrolling[Female]} = \text{Matriculants[Female]} * \text{Access_to_Financial_Aid} * \text{Engineering_Attractiveness_to_Tertiary_Enrollments[Female]}$
 - ↻ $\text{Changing_Career_Choice[People]} = \text{Matriculants[People]} - \text{Enrolling[People]}$
- $\text{Ops_ \& _Maint_Engineering_Skills_in_Eskom}(t) = \text{Ops_ \& _Maint_Engineering_Skills_in_Eskom}(t - dt) + (\text{Utilising_Graduates} + \text{Utilising_Professionals} + \text{Utilising_Experienced_Professionals}) * dt$
 INIT $\text{Ops_ \& _Maint_Engineering_Skills_in_Eskom} = 9000$
- INFLOWS:
- ↻ $\text{Utilising_Graduates} = \text{Technical_Requirement_for_Ops_ \& _Maint} * \text{Eskom_Engineering_Graduates}$
 - ↻ $\text{Utilising_Professionals} = \text{ECSA_Recognised_Professionals_in_Eskom} * \text{Technical_Requirement_for_Ops_ \& _Maint}$
 - ↻ $\text{Utilising_Experienced_Professionals} = (\text{IF}(\text{Internal_Appeal_of_Eskom_Capital_Expansion} > 1) \text{ THEN}((1 - \text{Internal_Appeal_of_Eskom_Capital_Expansion}) * \text{Ops_ \& _Maint_Engineering_Skills_in_Eskom}) \text{ ELSE}((1 - \text{Internal_Appeal_of_Eskom_Capital_Expansion}) * \text{Capacity_Expansion_Engineering_Skills_in_Eskom})) * \text{Required_Experience}$
- $\text{South_African_Engineering_Companies}(t) = \text{South_African_Engineering_Companies}(t - dt) + (\text{Utilising_Professionals_Nationally} + \text{Moving_of_Experienced_Professionals_Nationally} + \text{National_Recruiting_of_Graduates}) * dt$
 INIT $\text{South_African_Engineering_Companies} = 4000 * 40 * 0.5$
- INFLOWS:
- ↻ $\text{Utilising_Professionals_Nationally} = (\text{IF}(\text{Image_of_Electricity_Industry_Nationally} > 1) \text{ THEN}((1 - \text{Image_of_Electricity_Industry_Nationally}) * \text{South_African_Engineering_Companies}) \text{ ELSE}((1 - \text{Image_of_Electricity_Industry_Nationally}) * \text{ECSA_Recognised_Professionals_in_Eskom})) * \text{Required_Experience}$

- $\text{Matric_Pass_Rate[Female]} = 59/100 + \text{Eskom_Matric_Teacher_and_Student_Support}$
- $\text{National_Appeal_of_Eskom_Capital_Expansion} =$
 $\text{Internal_Appeal_of_Eskom_Capital_Expansion} * \text{Image_of_Electricity_Industry_Nationally}$
- $\text{Opportunity_for_Growth} = 110/100$
- $\text{Percentage_Mentors} = 5/100 + (45/100 * \text{Eskom_Mentorship_Program})$
- $\text{Perception_of_South_Africa} = 60/100$
- $\text{Rate_of_Retirement} = 2.5/100$
- $\text{Recruitment_Rate} =$
 $\text{Image_of_Electricity_Industry_Nationally} * \text{Recruitment_Aggressiveness} * \text{Engineering_Skill_Demand}$
- $\text{Recruitment_Aggressiveness} = 20/100$
- $\text{Relative_Salary} = 60/100$
- $\text{Required_Experience} = 10/100$
- $\text{Social_Investment_Visibility} = 60/100$
- $\text{Students_per_year[White_Male]} = 25000$
- $\text{Students_per_year[Black_Male]} = 203000$
- $\text{Students_per_year[Female]} = 275000$
- $\text{Technical_Requirement_for_Ops_ \& _Maint} = 5/100$

APPENDIX 3: ANALYSIS OF UPDATED SYSTEMS DYNAMICS MODEL

Figure 27 through to Figure 37 provide the graphical representations of the impact that changes of each of the variables has on the engineering skills for the capital expansion programme.

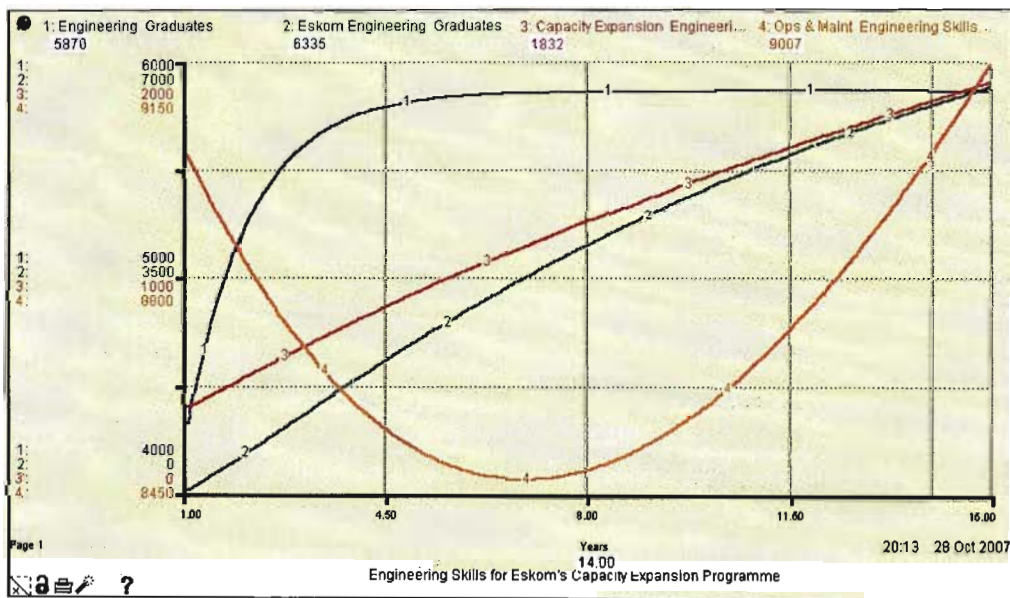


Figure 27 Eskom Matric Teacher and Student Support = +20%

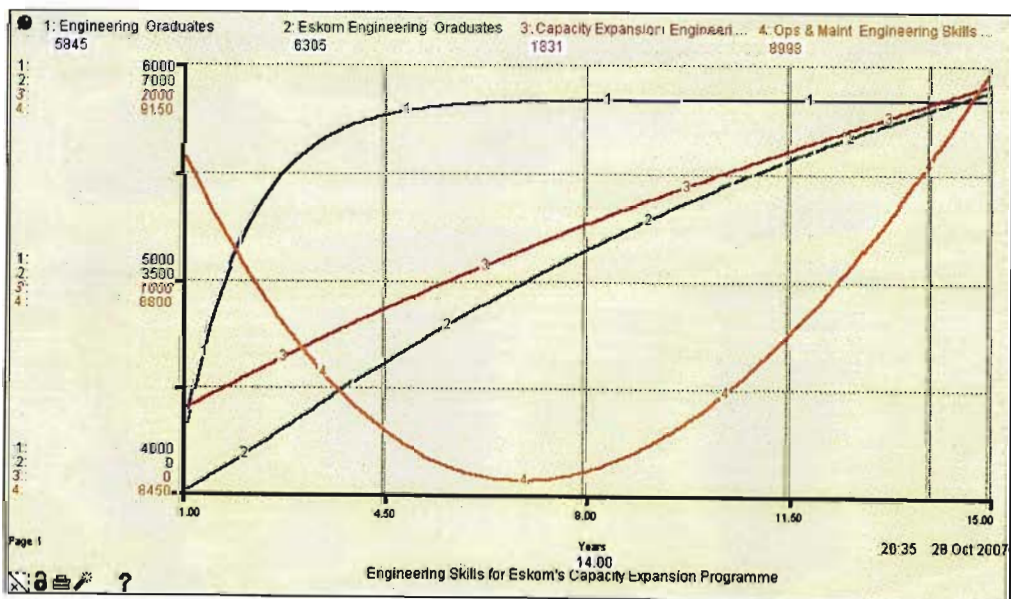


Figure 28 Eskom Financial Support Programme = +20%

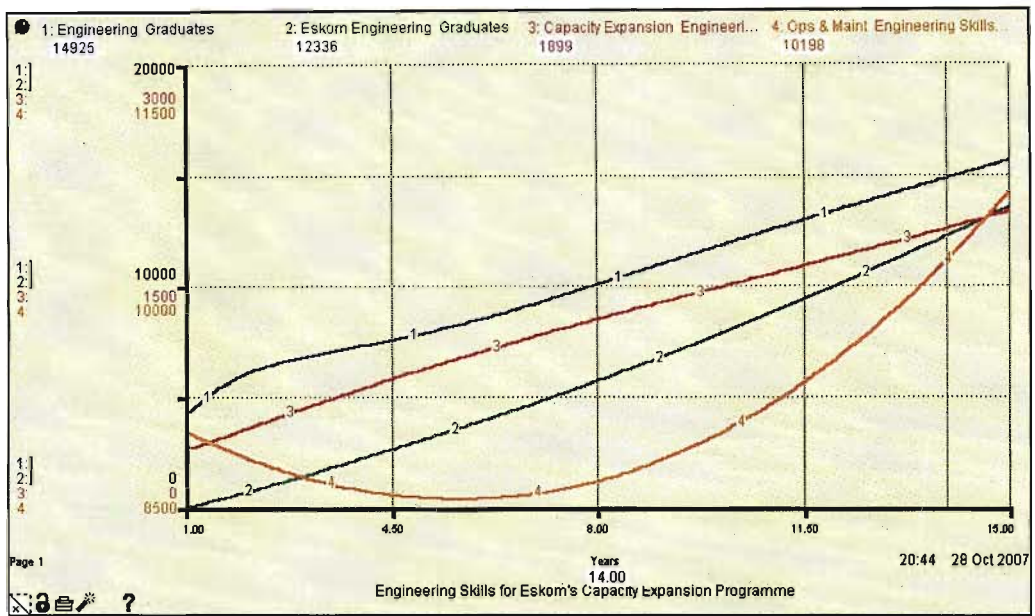


Figure 29 Eskom Engineering Promotion at Schools = +20%

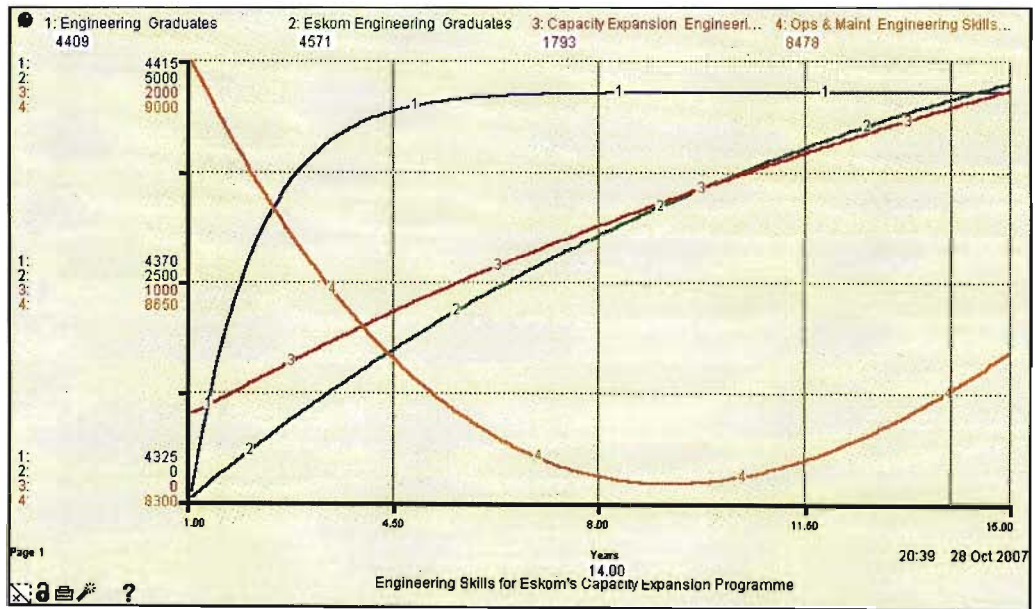


Figure 30 Engineering Attractiveness to Tertiary Enrollments [White Male] = +5%

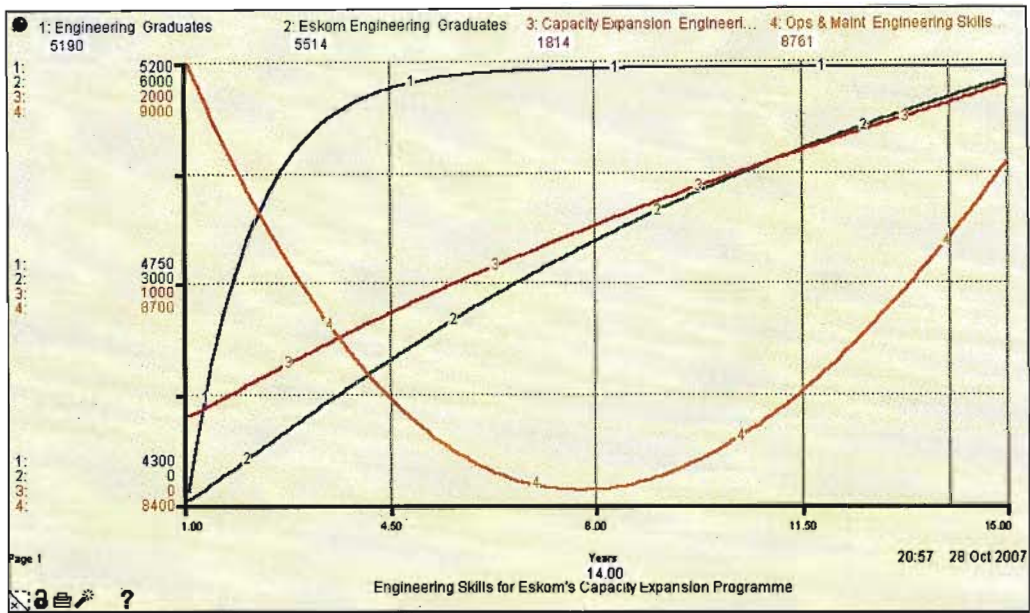


Figure 31 Engineering Attractiveness to Tertiary Enrollments[Black Male] = +20%

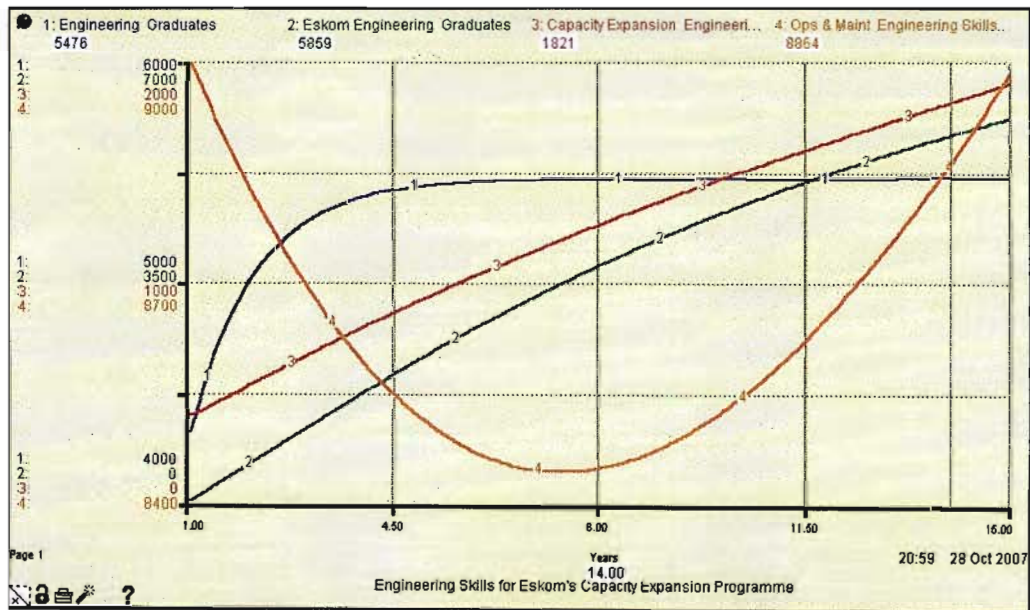


Figure 32 Engineering Attractiveness to Tertiary Enrollments[Female] = +20%

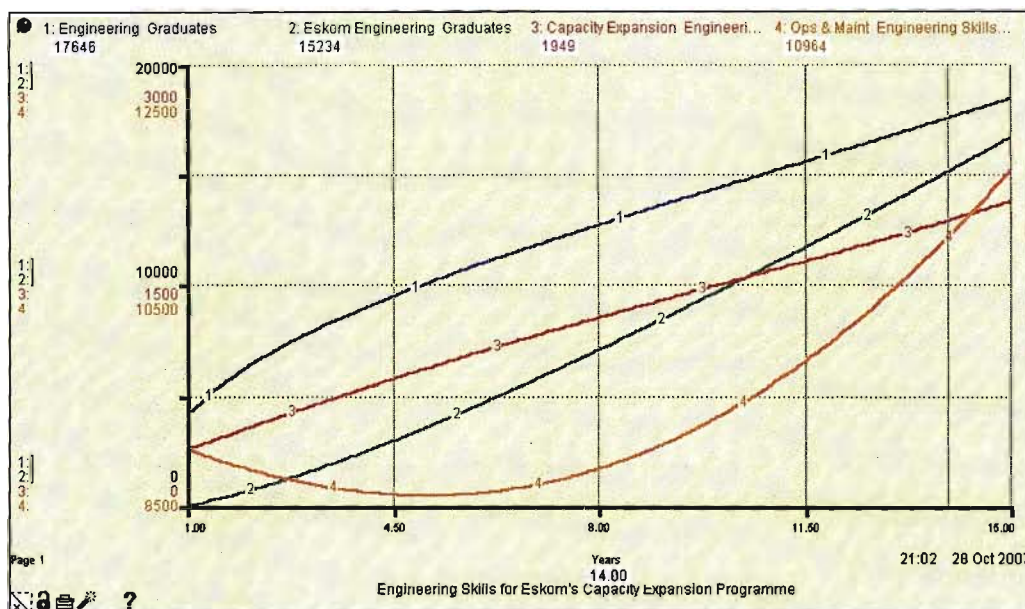


Figure 33 Effectiveness of Eskom Tertiary Support Initiatives = +10%

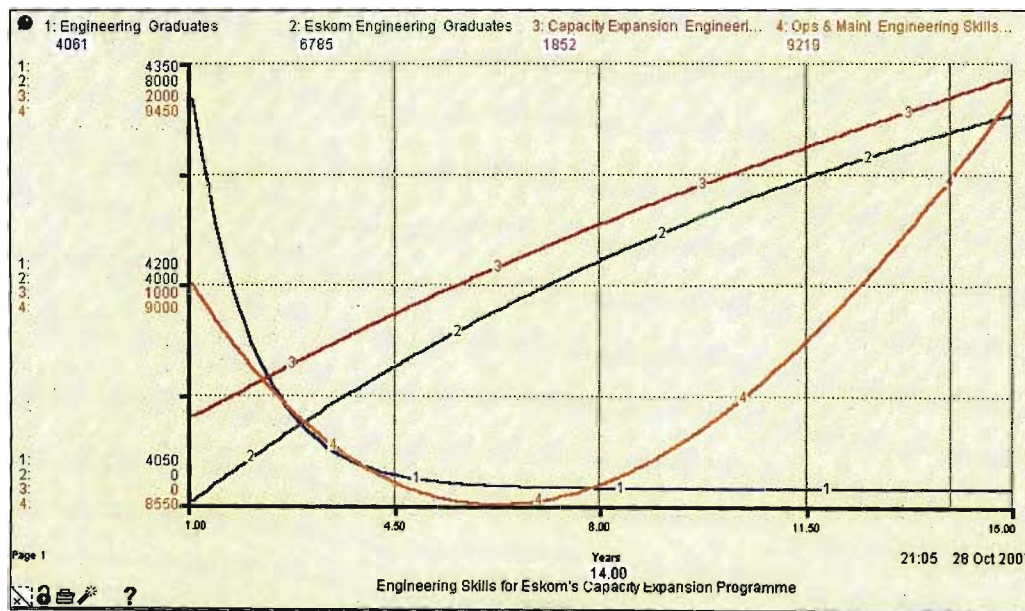


Figure 34 Recruitment Aggressiveness = +10%

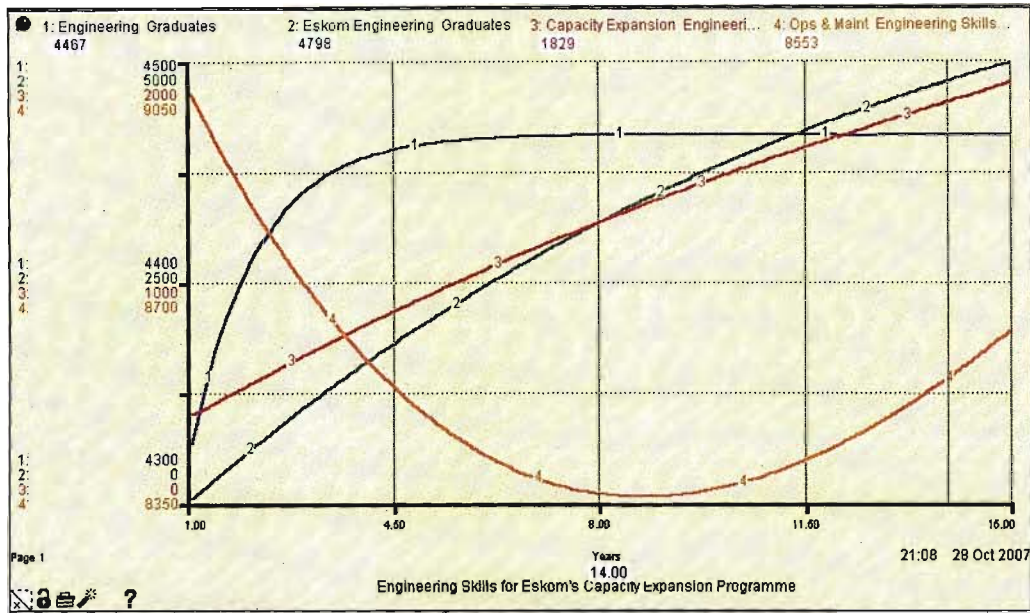


Figure 35 Multiple Variables taken individually = +10%

The Coolness Factor, Job Stability, Relative Salary, Environmental Initiatives Visibility and Social Investment Visibility were increased (individually) by 10% and all had the same effect as depicted in Figure 35.

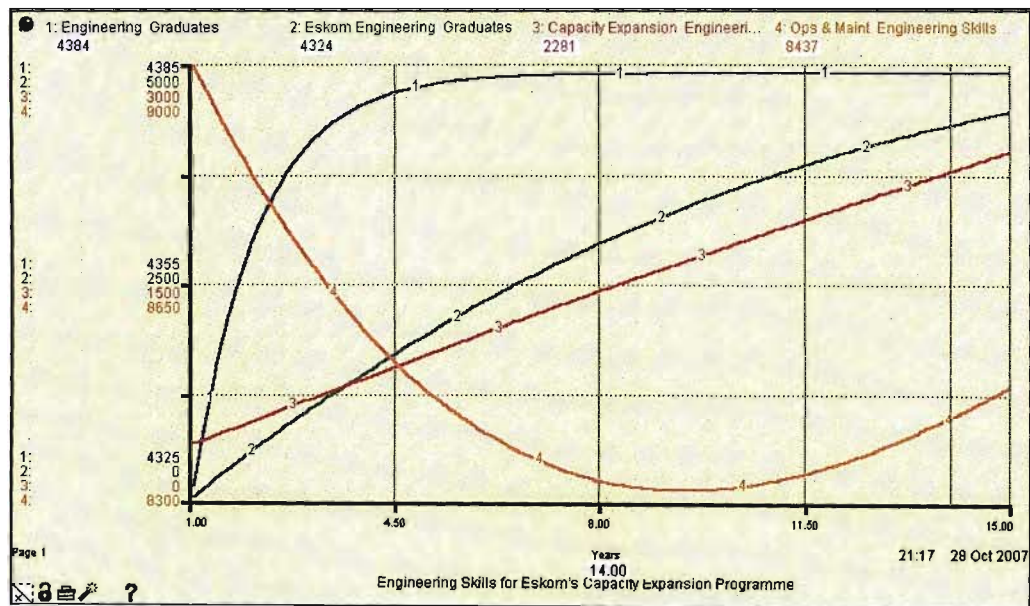


Figure 36 Eskom International Marketing Initiatives = +75%

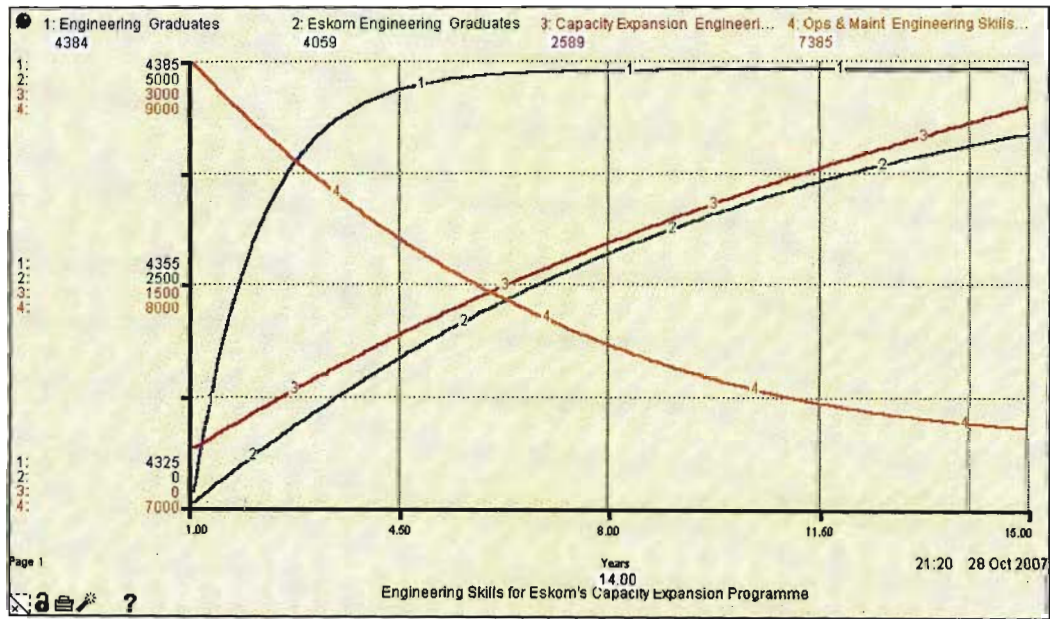


Figure 37 Eskom Capital Expansion Relative Internal Salary= +10%

APPENDIX 4: SUMMARY OF INTERVIEWEES' RESPONSES

The responses of each of the interviewees is summarised (in chronological order of when the interviews were conducted) in the subsequent sub-sections according to Table 12: Interview process per interviewee as provided on page 4.

ENGINEER IN TRAINING: CHRISTOPH KOHLMAYER

#	Question Category	Response
1	Personal Details	1. Age ? 26 years. 2. Qualifications: institute and when ? Honours Degree in Electronic Engineering, University of Pretoria, 2003. Completing a Masters Degree in Electronic Engineering. 3. Years in Eskom ? 21 months 4. Years in Enterprises Division and EED ? ~ 1 year 5. Title of position currently filled ? Assistant Engineer
2	Pre-prepared questions	The questions asked in this segment of the interview are selected as per Table 18 of Appendix 1: List of Questions per Interviewee: 1. Do you know what is expected of you at work? Yes. However, a documented job description has not been provided. Christoph suggested that a job description should be provided. 2. Do you have the right materials and equipment you need to do your work right? Yes. However, Christoph spoke of it being hard to find information. The example given was that of finding information in the library. 3. Do you have the opportunity to do what you do best every day? Yes. However, it would be helpful if commissioning experience at site could be gained. 4. Is there someone at work who encourages your development? Yes.

		<p>5. Have you had adequate training for the job ? Academically: No, instrumentation and project management was not covered adequately at university.</p> <p>On the job: Yes. Sufficient training opportunities.</p> <p>6. What should we be doing and not be doing to alleviate engineering skills shortage in Eskom ? Addressed in Category 4 below: Alternative Interventions.</p>
3	Current Interventions	<p>The interviewee’s perspective on the impact of current interventions as listed in Table 2: Description and classification of current interventions</p> <p>Summary is as per Table 14: Summary of Perceived Impact of current interventions undertaken by Eskom. In addition, the following significant comments were made:</p> <ol style="list-style-type: none"> 1. Bursary programme needs an Open Day at universities. 2. Mentorship and Training Programme: <ol style="list-style-type: none"> a. There needs to be an initial formal assignment of a mentor, b. The number of mentors registered with ECSA is low. c. The Generation Skills Development Programme was a good training programme. d. Secondment to Original Equipment Manufacturers (OEMs) is suggested. 3. Improved Systems: Eskom procurement systems are too slow. It takes too long to purchase the tools that are needed e.g. purchase of optimisation software. 4. Partnership with Other Companies: Christoph suggested that this form of intervention not be used, since from his experience, the skills tend to remain with the other engineering company’s resources. 5. GARP & TASK: Salary at engineer-in-training level is

		<p>not market-related compared to friends outside of Eskom.</p> <p>6. Partnership between Eskom & Higher Education: Christoph stated that there were only ~ 3 or 4 out of ~150 first year electronic engineering undergraduates who had bursaries from Eskom at the University of Pretoria... too low.</p> <p>7. <u>Use of Retirees (Added Intervention 12):</u> This has worked at sites e.g Camden, but not at central engineering.</p> <p>8. <u>Use of Generation resources (Added Intervention 13):</u> This has not had a significant effect on the engineering skills within the expansion effort at Eskom.</p>
4	Alternative Interventions	<p>The interviewee was requested to suggest alternative interventions to those identified in Table 2: Description and classification of current interventions</p> <p>It was suggested that Eskom should pursue the following interventions:</p> <ol style="list-style-type: none"> 1. Approach students prior to matric, as early as Grade 9 (prior to them choosing subjects for Grades 10 to 12) to inform of engineering and career in electricity industry. 2. Provide pre-Matric students with equipment that will create a “fascination” with engineering and technology. 3. Provide an incentive scheme to mathematics and science teachers. 4. Eskom should not [duplicate the efforts of existing universities] when setting up the “Eskom University”. 5. Issue questionnaires to employees to gain an understanding of their concerns and what they like about their jobs. Don’t only do this when they are leaving ... then it is too late. 6. The main route (medium to long term) for skill shortage alleviation should be by providing bursaries

		<p>to undergraduates and the use of resources from other companies can be used as a short term solution.</p>
5	Draft Systems Dynamics Model	<p>The draft systems dynamics model provided in Figure 15 on page 4 was presented to the interviewee. Suggestions for improvement to this systems dynamics model was sought from the interviewee.</p> <p>Christoph suggested including a portion that created “fascination” in mathematics and science students from as early as Grade 9.</p> <p>Students must have engineering marketed early on. Specifically mentioned salary.</p>
6	Other Suggestions and Comments	<p>Apart from the guided responses sought from the interviewee on alternative suggestions and improvements to the systems dynamics model, an unguided response was sought from the interviewee on any other suggestions and comments for the author of this dissertation to consider.</p> <p>All people should be given equal opportunity in engineering... don't reject anyone.</p> <p>The image of engineering needs to be improved in South Africa ... look at Germany, where engineers get to utilise prefix titles signifying that they are engineers.</p> <p>Mathematics and science are taken in the schools, but not for engineering (rather for medicine-related fields).</p> <p>At Pretoria University, Christoph noticed that there were many Industrial and Chemical engineering female students and Electronic and Mechanical engineering black students.</p>

Table 19 Interview Summary: Christoph Kohlmeyer

CHIEF ENGINEER: JOHANNES VAN TONDER

#	Question Category	Response
1	Personal Details	<p>1. Age ? 39 years.</p> <p>2. Qualifications: institute and when ? Bachelor of Engineering (Electronic), University of Pretoria, [no date requested]. Master of Engineering (Control Systems), University of Pretoria, [no date requested]. Master of Engineering (Project Management), University of Pretoria, [no date requested].</p> <p>3. Years in Eskom ? 14.5 years</p> <p>4. Years in Enterprises Division and EED ? 3 years</p> <p>5. Title of position currently filled ? Chief Engineer</p>
2	Pre-prepared questions	<p>The questions asked in this segment of the interview are selected as per Table 18 of Appendix 1: List of Questions per Interviewee:</p> <p>1. From your perspective, how large is the engineering skills shortage in Eskom ? It is large. In terms of numbers we have about $\frac{1}{2}$ to $\frac{2}{3}$ of the engineering skill that we require and in terms of skill level, it is $\frac{1}{2}$ of what we require.</p> <p>Very little money has been spent on engineering in the last few years therefore the universities have not increased their output.</p> <p>2. What manifestation of the engineering skills shortage in Eskom do you see in the work we do ? Quality of what is produced is lower and the cost is higher. Unsure of the effect on time.</p>

		<p>3. What should we be doing and not be doing to alleviate engineering skills shortage in Eskom ? Addressed in Category 4 below: Alternative Interventions.</p> <p>4. What skills do the junior staff lack ? They lack understanding the process of engineering (Systems Engineering knowledge). They receive sufficient technical knowledge, however they have not been taught how to apply this knowledge. The engineering problem solving process is not understood. The author of this dissertation and Johannes both confirmed that they also did not receive this problem solving skill at university and only developed it later on in the careers.</p> <p>5. How can these skills be developed ? Through Vacation work that will enable the students to prepare for the work environment. Need to understand how power is produced and the engineering process.</p> <p>Need to gain skills in project management.</p> <p>Need communication, report writing and presentation skills.</p>
3	Current Interventions	<p>The interviewee’s perspective on the impact of current interventions as listed in Table 2: Description and classification of current interventions.</p> <p>Summary is as per Table 14: Summary of Perceived Impact of current interventions undertaken by Eskom. In addition, the following significant comments were made:</p> <ol style="list-style-type: none"> 1. Although there is the effort to pull people in through the accelerated recruitment drives, the supply is not there i.e the people are simply not available. 2. When it comes to bursaries, the commitment and time spent on bursary provision is inadequate. Resources are required for this. 3. In terms of improved systems, the adverse effect could be experienced by Eskom i.e quality could go down.

		<ol style="list-style-type: none"> 4. Partnerships with other companies in terms of training does not allow for information sharing due to the other company's business model. 5. Although the GARP and TASK initiative is necessary for retention, it is not sufficient. Other factors need to be considered. 6. It is positive, however more needs to be done to keep the bursars interested and informed on the what is happening in Eskom through presentation, discussions, social events etc. 7. The partnership with higher education institutions needs more effort, eg. sponsor of lecturers as Chairs. 8. When it comes to the AsgiSA and JIPSA, the resources are not only for Eskom. There is also the social responsibility. 9. When recruiting from Eskom operating and maintenance divisions, thought must be given to "not reducing the installed base" i.e. having power outages due to plant that has not been maintained adequately.
4	Alternative Interventions	<p>The interviewee was requested to suggest alternative interventions to those identified in Table 2: Description and classification of current interventions</p> <p>It was suggested that Eskom should pursue the following interventions:</p> <ol style="list-style-type: none"> 1. Johannes stated that finding engineers is not the solution as we will be still in the same pool of resources. He believes that we should build our engineering resources and start from Grade 9/10. We <u>must</u> invest time and money. 2. It was suggested that the knowledge of the public at large must be increased in terms of what Eskom is, how is electricity generated etc. <p>He stated that we need to advertise engineering as a whole at</p>

		<p>this Grade 9/10 level. Need to encourage maths and science. Suggested the use of school bursaries.</p> <p>He suggested the sponsoring of lecturers as Chairs at universities for example at University of Pretoria, Denel & Kentron sponsored Chairs when the defence industry was doing well.</p> <p>Johannes supported the concept of an Eskom university. The details of the concept are still not clear at this stage, but he spoke of John Gosling co-ordinating training in Eskom. He believes that this will be the means to focus the training and quality on Eskom's needs.</p> <p>Johannes suggested that 3rd/4th year students' projects should be sponsored by Eskom. This will ensure that Eskom's needs are addressed and the content & quality of education can be controlled by Eskom.</p> <p>In addition, Johannes stated that we must <u>not</u> buy in overseas expertise. We must instead put our people (South African citizens) there in their training institutes.</p> <p>Re-emphasised that money and effort needs to be spent in <u>developing</u> the engineering skill.</p>
5	Draft Systems Dynamics Model	<p>The draft systems dynamics model provided in Figure 15 on page 4 was presented to the interviewee. Suggestions for improvement to this systems dynamics model was sought from the interviewee.</p> <p>Johannes suggested including interest and exposure to engineering from as early as Grade 9 so that students can make an informed career choice. The quantities of graduates are lacking in terms of what we are producing.</p>
6	Other Suggestions	<p>Apart from the guided responses sought from the interviewee on alternative suggestions and improvements to the systems</p>

	and Comments	dynamics model, an unguided response was sought from the interviewee on any other suggestions and comments for the author of this dissertation to consider. Re-emphasized that time and effort needs to be spent on developing our resources.
--	-----------------	---

Table 20 Interview Summary: Johannes van Tonder

SENIOR GENERAL MANAGER (NUCLEAR PROGRAMME): CLIVE LE ROUX

#	Question Category	Response
1	Personal Details	<p>1. Age ? 55 years.</p> <p>2. Qualifications: institute and when ? Bachelors Engineering</p> <p>3. Years in Eskom ? 34 years</p> <p>4. Years in Enterprises Division and EED ? 3 years.</p> <p>5. Title of position currently filled ? Senior General Manager (Nuclear Programme)</p>
2	Pre-prepared questions	<p>The questions asked in this segment of the interview are selected as per Table 18 of Appendix 1: List of Questions per Interviewee:</p> <p>1. From your perspective, how large is the engineering skills shortage in Eskom ? Massive in two fronts: qualified and experienced people. Short of headcount and short on [level] of skills.</p> <p>Clive sees four levels of engineering professionals as per ECSA: professional engineers, (professional engineering technologists + professional certificated engineers) and professional technicians.</p> <p>Clive sees the number shortage as 50% and sees the skill level as 10% of what we need to deliver an integrated project, even though some of the standalone e.g. Electrical engineering or Control & Instrumentation engineering has about 70% of the skill.</p> <p>EED needs 800 versus the current 400 people to meet the long term needs of the current contracting strategy (Coal-fired, Hydro and Gas Turbines power). This has a skill base of 9000 in Eskom Generation to develop the additional 400 from.</p>

	<p>Whilst, the nuclear programme needs 7000 engineering staff [localisation option] versus the current 2 available people, therefore the current skill base for the nuclear programme is ~0%. However, the existing nuclear skill base is 1000 [at essentially Koeberg] and not available for usage in the Nuclear programme.</p> <p>Strategy for filling the skill gap for the nuclear programme should be different than that of EED.</p> <p>2. What manifestation of the engineering skills shortage in Eskom do you see in the work we do ?</p> <p>It appears as [poorer] quality, time and cost overruns. There is a worldwide shortage of [skill] capacity], that is causing a greater demand and hence higher salary demands.</p> <p>3. What interaction do you have with Eskom Human Resources (HR) and Training in terms of engineering skills shortage in Eskom ?</p> <p>In terms of Eskom Training, it is mainly around the Eskom University concept as tabled and approved by Executive Committee on 2006-04-25. However, the direction taken by the training department and is [apparently] different than that which was tabled and approved.</p> <p>The Eskom University concept is essentially that of a special purpose vehicle (SPV) in which other industry companies and Eskom contribute towards the funding of this SPV. The output in terms of trained graduates of this Eskom University is then used one third for Eskom, one third for the other contributing companies and then a last third for the non-contributing companies.</p> <p>EED approached the Eskom Training Department and proposed to setup a power plant option at Witwatersrand University. Similar to a nuclear option at University of Cape</p>
--	---

		<p>Town and the transmission equivalent at the University of KwaZulu Natal.</p> <p>Man Power planning committee with ED HR manager Matome Makwela on a 2-weekly basis.</p> <p>4. What should we be doing and not be doing to alleviate engineering skills shortage in Eskom ?</p> <p>Addressed in Category 4 below: Alternative Interventions.</p>
3	Current Interventions	<p>The interviewee’s perspective on the impact of current interventions as listed in Table 2: Description and classification of current interventions</p> <p>Summary is as per Table 14: Summary of Perceived Impact of current interventions undertaken by Eskom. In addition, the following significant comments were made:</p> <ol style="list-style-type: none"> 1. Accelerated recruitment is essentially a public relations initiative and has not provided any results. Example provided of a UK recruitment drive in which 1 week was spent to return with only 2 engineers (not key people). 2. The training programme in Eskom is not considered by ECSA as of good quality. This could be attributed to Eskom’s training programme not being centralised. 3. Execution of partnership is not successful due to culture mis-fits between the 2 companies and also due to companies not having enough resources. 4. Bursar Programme is poor and constrained by employment equity during the expansion programme. 5. Establishing Nuclear Faculties at each/selected universities together with the help of Department of Education. Strong support but action at the moment is not seen.
4	Alternative Interventions	<p>The interviewee was <u>not</u> requested to suggest alternative interventions to those identified in Table 2: Description and classification of current interventions due to the interview lasting</p>

		<p>longer than the allocated 90 minutes. However, during the interview, the interviewee suggested and that:</p> <p>Eskom should pursue the following interventions:</p> <ol style="list-style-type: none"> 1. Mentoring should be structured such that it is made up of career mentoring, functional mentoring and task mentoring. Spoke of having it as a centralised function. 2. Eskom University as per the Executive Committee approved concept.
5	Draft Systems Dynamics Model	<p>The draft systems dynamics model provided in Figure 15 on page 4 was presented to the interviewee. Suggestions for improvement to this systems dynamics model was sought from the interviewee.</p> <p>Clive mentioned theory of constraints to identify the places of constraints. Spoke of Eskom as a gender friendly company.</p>
6	Other Suggestions and Comments	<p>Apart from the guided responses sought from the interviewee on alternative suggestions and improvements to the systems dynamics model, <u>no other</u> unguided response was sought from the interviewee on any other suggestions and comments for the author of this dissertation to consider.</p> <p>However, Clive mentioned the need to get a conversation going between Eskom Training and himself regarding the Eskom University Concept.</p>

Table 21 Interview Summary: Clive Le Roux

ENGINEER: SAMANTHA KALI

#	Question Category	Response
1	Personal Details	<p>1. Age ? 30 years.</p> <p>2. Qualifications: institute and when ? BSc Eng (Electrical Light Current), University of Durban-Westville, 2002 (converted from a BSc (Chemistry) afters 2 years of study) Completed a Management Development Programme, Eskom, 2007 (Graduation in November)</p> <p>3. Years in Eskom ? 6 years</p> <p>4. Years in Enterprises Division and EED ? 2 years</p> <p>5. Title of position currently filled ? Engineer</p>
2	Pre-prepared questions	<p>The questions asked in this segment of the interview are selected as per Table 18 of Appendix 1: List of Questions per Interviewee:</p> <p>1. From your perspective, how large is the engineering skills shortage in Eskom ? It is a huge issue (not only at EED but also at operations level). Also skill loss at site is larger than at central. Spoke of it as a salary issue. Training programme is terrible at site. Spoke of Generation Skills Development Programme (GSDP) being an improvement.</p> <p>2. What manifestation of the engineering skills shortage in Eskom do you see in the work we do ? People at site were not properly trained and did not know the Eskom way of doing things. Quality is affected, rework needed, delays.</p> <p>3. What should we be doing and not be doing to alleviate engineering skills shortage in Eskom ? Addressed in Category 4 below: Alternative Interventions.</p>

3	Current Interventions	<p>The interviewee's perspective on the impact of current interventions as listed in Table 2: Description and classification of current interventions</p> <p>Summary is as per Table 14: Summary of Perceived Impact of current interventions undertaken by Eskom. In addition, the following significant comments were made:</p> <ol style="list-style-type: none"> 1. People with 5 to 10 years is lacking. There is an inflow of young and there is a number of older people. 2. There is a mentorship programme, however it is not followed through i.e. there is no enforcement. 3. Not enough mentors who give broad career mentorship. 4. Processes need to be strict and enforced. 5. Partnership is not working due to the other companies not doing work as Eskom does work. 6. Currently not market related salaries for PA0 band [entry level professional band according to Patterson grading system]. 7. What was studied at university was not what Samantha has been required to do at work. 8. Samantha does not think there is a difference between women and men engineers in what they can do. In fact she thinks that lady engineers are better than men engineers. Women engineers want to prove to themselves that they can do it. 9. Retirees generally do not have up-to-date knowledge. 10. New people should be used in Generation and the experienced people should then come through to the Capital expansion programme. 11. Efforts on paper looks to be good, however the fruits of the implementation does not seem to be coming through. There seems to be a implementation problem.
---	-----------------------	---

4	Alternative Interventions	<p>The interviewee was requested to suggest alternative interventions to those identified in Table 2: Description and classification of current interventions</p> <p>The following comments were offered:</p> <ol style="list-style-type: none"> 1. The mentorship programme needs effort. 2. Processes are not defined, therefore we are not sure of the objectives and hence no job satisfaction. 3. Recruitment of ladies is done blindly .i.e. window dressing. 4. Engineering is not seen as a totally male dominated field. 5. Load losses are common due to properly skilled people leaving site. Training is very impotant prior to performing work on site.
5	Draft Systems Dynamics Model	<p>The draft systems dynamics model provided in Figure 15 on page 4 was presented to the interviewee. Suggestions for improvement to this systems dynamics model was sought from the interviewee.</p> <p>Samantha spoke of women having an anticipation of earning [a lot of] money in engineering and then moving on to management due to this expectation not being met.</p> <p>Although people get Eskom bursaries, they do not have defined roles of what they are going to be doing when they get into Eskom.</p> <p>Samantha sees the effort of having interventions using Eskom staff to provide student support to improve the engineering student pass rates as not being of use.</p> <p>Samantha suggested that sending Eskom women engineers to do marketing at the school level. She suggested understanding why the women don't choose engineering at the earlier stage.</p>

		<p>An engineer is innovative and needs to understand a little bit of everything, not only mathematics and science. Need to promote engineering in a different way: more holistic use of knowledge.</p> <p>Some engineers get bored and subsequently frustrated. Suggest changing the field that an engineer is working in.</p> <p>Samantha spoke of site mentorship as being non-existent.</p>
6	Other Suggestions and Comments	<p>Apart from the guided responses sought from the interviewee on alternative suggestions and improvements to the systems dynamics model, an unguided response was sought from the interviewee on any other suggestions and comments for the author of this dissertation to consider.</p> <p>Samantha asked about the use of overseas resources. Spoke of Australian recruitment drive at Gallagher Estates to utilise South African engineers.</p> <p>What is happening to the engineering graduates being produced by India and China ? We have to look outwards.</p>

Table 22 Interview Summary: Samantha Kali

SENIOR TECHNICIAN: EUGENE MOTSOATSOE

#	Question Category	Response
1	Personal Details	<p>1. Age ? 34 years.</p> <p>2. Qualifications: institute and when ? B Tech (Electrical Engineering Light Current), Witwatersrand Technikon, 2004. Currently completing the Technology Leadership Programme, Eskom, 2007.</p> <p>3. Years in Eskom ? 10 years</p> <p>4. Years in Enterprises Division and EED ? 3 years</p> <p>5. Title of position currently filled ? Senior Technician</p>
2	Pre-prepared questions	<p>The questions asked in this segment of the interview are selected as per Table 18 of Appendix 1: List of Questions per Interviewee:</p> <p>1. From your perspective, how large is the engineering skills shortage in Eskom ? Eugene perceives the problem to be normal relative to other companies. He believes the criteria of ECSA requirements to be a constraint.</p> <p>He believes that we have not defined what we want adequately in terms of core skills.</p> <p>In addition, the training initiatives in Eskom is inadequate. The training center in the Eskom Convention Center is under-utilised.</p> <p>Do not train people with technical skills and then employ them in positions that they do not use those skills.</p>

		<p>2. What manifestation of the engineering skills shortage in Eskom do you see in the work we do ?</p> <p>Quality of output is low. In addition, there are more stressed and unhappy personnel.</p> <p>3. What should we be doing and not be doing to alleviate engineering skills shortage in Eskom ?</p> <p>Addressed in Category 4 below: Alternative Interventions.</p> <p>4. What skills do the junior staff lack ?</p> <p>Need to assess what level the person is at and we need to define the job to be performed. Basic engineering concepts e.g the use of inductors. Lack of practical skills.</p> <p>5. How can these skills be developed ?</p> <p>More attention must be given on the assessment of people coming into the organisation in terms of their basic engineering skills and attitude. If not this results in frustration.</p>
3	Current Interventions	<p>The interviewee’s perspective on the impact of current interventions as listed in Table 2: Description and classification of current interventions</p> <p>Summary is as per Table 14: Summary of Perceived Impact of current interventions undertaken by Eskom. In addition, the following significant comments were made:</p> <ol style="list-style-type: none"> 1. Need to use all available mediums and languages to advertise the recruitment. 2. Culture of “idleness”. Need to regularly speak to the students. Background of education amongst Blacks was “spoon feeding”. 3. In terms of the partnerships with other companies, the training has not been defined sufficiently. 4. Recruitment drives is seen to be part of the partnerships with the universities. Need to instill a realistic expectation of what Eskom can offer to engineering

		<p>graduates in terms of salaries, training and job functions.</p> <ol style="list-style-type: none"> 5. Government Partnerships: Implementation does not meet the intent. 6. Eskom University should be a partnership with other companies to lower the skills poaching by these companies. 7. We don't create that passion for maths and science. 8. Recruitment from Generation is just moving people around.
4	Alternative Interventions	<p>The interviewee was requested to suggest alternative interventions to those identified in Table 2: Description and classification of current interventions</p> <p>It was suggested that Eskom should pursue the following interventions:</p> <ol style="list-style-type: none"> 1. Financial Aid: understand the background of people. 2. Image of Eskom: A caring company. Sponsor soccer teams, become visible. 3. Understanding of what Eskom is and how electricity is "made"
5	Draft Systems Dynamics Model	<p>The draft systems dynamics model provided in Figure 15 on page 4 was presented to the interviewee. Suggestions for improvement to this systems dynamics model was sought from the interviewee.</p> <p>Eugene spoke of providing family support loan, apart from bursary. The student should get information about engineering in standard 6 (Grade 8) to have a clear picture of engineering before they make their choice.</p> <p>As a black lady, it is not easy to get through studying for engineering. They are expected to do a lot of chores around the house whilst studying.</p> <p>We keep saying that maths and science is difficult and</p>

		<p>engineering is a combination of this difficult subjects.</p> <p>We need to tell the kids that they are smart and motivate them.</p> <p>People being moved back and forth across the different divisions is not going to help.</p> <p>Make engineering [to be perceived as] cool to high school students.</p> <p>There still are social differences between the different races e.g a black student staying in the a match box house with 5 other people and cannot study easily.</p>
6	Other Suggestions and Comments	<p>Apart from the guided responses sought from the interviewee on alternative suggestions and improvements to the systems dynamics model, an unguided response was sought from the interviewee on any other suggestions and comments for the author of this dissertation to consider.</p> <p>Train the people and even use testing as an assessment medium.</p> <p>The criteria to pull people in needs to give people a chance that have not completed the qualification as yet.</p>

Table 23 Interview Summary: Eugene Motsoatsoe

ENGINEER: ZUBAIR MOOLA

#	Question Category	Response
1	Personal Details	<p>1. Age ? 24 years.</p> <p>2. Qualifications: institute and when ? Bachelor of Science in Engineering (Electronic), University of Kwa-Zulu Natal, 2004.</p> <p>3. Years in Eskom ? 3 years.</p> <p>4. Years in Enterprises Division and EED ? 6 months (moved to EED from Transmission Division).</p> <p>5. Title of position currently filled ? Engineer</p>
2	Pre-prepared questions	<p>The questions asked in this segment of the interview are selected as per Table 18 of Appendix 1: List of Questions per Interviewee:</p> <p>1. From your perspective, how large is the engineering skills shortage in Eskom ? Opinion is only based on what he has read. Currently not experienced in C&I department. Zubair thinks that this would have been seen if there were people that were overloaded. Currently he perceives that we are not overloaded.</p> <p>2. What manifestation of the engineering skills shortage in Eskom do you see in the work we do ? We do not have enough people to complete walkdowns at Duvha power station.</p> <p>3. Do you know what is expected of you at work? Yes. He has a job description.</p> <p>4. Do you have the opportunity to do what you do best every day? Once he gets into the thick of things, he feels he should be able to add value.</p>

		<p>5. Is there someone at work who encourages your development? Yes (Dieter Huppe + Brendan Moodley). No assigned mentor. He can't just feel around.</p> <p>6. Have you had adequate training for the job ? Yes. He is undergoing training.</p>
3	Current Interventions	<p>The interviewee's perspective on the impact of current interventions as listed in Table 2: Description and classification of current interventions</p> <p>Summary is as per Table 14: Summary of Perceived Impact of current interventions undertaken by Eskom. In addition, the following significant comments were made:</p> <ol style="list-style-type: none"> 1. Zubair appreciates the informal training approach in the C&I department. 2. The training from partnerships with other companies would be helpful. 3. When Zubair was at university, he had 25 to 30 Eskom bursars of which 50 % were ladies. 4. On the Generation Skills Development Programme that Zubair attended, there were 23 trainees, 20 black females, 1 white female, 2 black males. Total per year = ~120. 5. Mentioned the Talent 100 initiative: 100 Black women graduates. 6. Suggested that we have an Enterprises Division Masters Programme with one of the universities. 7. Zubair suggested looking at why are we producing so few graduates.
4	Alternative Interventions	<p>The interviewee was requested to suggest alternative interventions to those identified in Table 2: Description and classification of current interventions</p> <p>Zubair suggested that Eskom should:</p> <ol style="list-style-type: none"> 1. Pursue the recruitment of graduates from the east. 2. Make engineering more attractive to younger people,

		<p>3. Eskom should go on a drive to universities to give bursaries to third and fourth year students.</p>
5	Draft Systems Dynamics Model	<p>The draft systems dynamics model provided in Figure 15 on page 4 was presented to the interviewee. Suggestions for improvement to this systems dynamics model was sought from the interviewee.</p> <p>Zubair suggested:</p> <ol style="list-style-type: none"> 1. Interest to maths, science and engineering in young people should be created. 2. Retirees re-entering must be modelled. 3. Employment equity must be relaxed. Which is of higher priority: numbers or employment equity ?
6	Other Suggestions and Comments	<p>Apart from the guided responses sought from the interviewee on alternative suggestions and improvements to the systems dynamics model, an unguided response was sought from the interviewee on any other suggestions and comments for the author of this dissertation to consider.</p> <p>Use successful engineers to change people’s perception of engineering as a male dominated field at an earlier stage.</p>

Table 24 Interview Summary: Zubair Moola

CONTROL & INSTRUMENTATION MANAGER: DIETER HUPPE

#	Question Category	Response
1	Personal Details	<p>1. Age ? 53 years.</p> <p>2. Qualifications: institute and when ? National Higher Diploma. Witwatersrand Technickon, [date not requested].</p> <p>3. Years in Eskom ? 31 years</p> <p>4. Years in Enterprises Division and EED ? 3 years</p> <p>5. Title of position currently filled ? Control & Instrumentation (C&I) Engineering Manager</p>
2	Pre-prepared questions	<p>The questions asked in this segment of the interview are selected as per Table 18 of Appendix 1: List of Questions per Interviewee:</p> <p>1. From your perspective, how large is the engineering skills shortage in Eskom ? We have a big problem and the only way he sees, is that we carry out skills development. Market forces are having a large influence. Capacity expansion is understaffed. C&I is currently 17 but should be around 50.</p> <p>2. What manifestation of the engineering skills shortage in Eskom do you see in the work we do ? We going to have some mishaps. Quality and standardisation is going to go down.</p> <p>3. What interaction do you have with Eskom Human Resources (HR) and Training in terms of engineering skills shortage in Eskom ? HR add very little value in the recruitment process. It takes a minimum of 2 months to get someone external to the organisation into Eskom. It should really take 2 weeks.</p>

		<p>Training development and skills planning is discussed and agreed with HR.</p> <p>4. What should we be doing and not be doing to alleviate engineering skills shortage in Eskom ?</p> <p>Addressed in Category 4 below: Alternative Interventions.</p>
3	Current Interventions	<p>The interviewee’s perspective on the impact of current interventions as listed in Table 2: Description and classification of current interventions</p> <p>Summary is as per Table 14: Summary of Perceived Impact of current interventions undertaken by Eskom. In addition, the following significant comments were made:</p> <ol style="list-style-type: none"> 1. We should have a higher activity level when the students come out of secondary school. 2. Overloading of staff and mindset of people also plays a part as to the effectiveness of the mentorship and training programme. 3. No processes mean we are all not swimming in the same direction. 4. The implementation of the Intergraph system means that there is a risk of losing the innovation. 5. Outside companies don’t understand how Eskom works e.g. the commercial processes. Little knowledge transfer. 6. Bursaries should be awarded on merit. The line up with the engineering disciplines’ requirements is not there. There needs to be closer interaction between Eskom and the engineering students. 7. AsgiSA is helping by forcing the contractors (penalties are attached to it) to train people. 8. The Eskom University is not the right thing i.e. it must not be an Eskom initiative only. Need technical skills but not brainwashed in terms of what Eskom is doing i.e. you need diversity. 9. Need to realise that we need to develop the skills and not

		<p>focus on the other interventions. Need to utilise retirees as mentors and not as consultants.</p> <p>10. Engineering staff are being wasted at site.</p>
4	Alternative Interventions	<p>The interviewee was requested to suggest alternative interventions to those identified in Table 2: Description and classification of current interventions</p> <p>Although no alternative was suggested, Dieter wanted to work with getting people in from university and getting the youngsters excited about engineering.</p> <p>The level of skill in the disciplines depends on the technology change in that disciplines.</p> <p>IT was the area to study because everybody talked about it.</p>
5	Draft Systems Dynamics Model	<p>The draft systems dynamics model provided in Figure 15 on page 4 was presented to the interviewee. Suggestions for improvement to this systems dynamics model was sought from the interviewee.</p> <p>Different disciplines have different drivers in terms of who enters the discipline. Youngsters have a lack of direction. There is not enough career counselling at school. Need to identify direction and natural abilities. Define what the different jobs are.</p>
6	Other Suggestions and Comments	<p>Apart from the guided responses sought from the interviewee on alternative suggestions and improvements to the systems dynamics model, an unguided response was sought from the interviewee on any other suggestions and comments for the author of this dissertation to consider.</p> <p>Need to define what an engineer is and the different engineering disciplines.</p>

Table 25 Interview Summary: Dieter Huppe

HUMAN RESOURCES SHARED SERVICES MANAGER: ELSIE PULE

#	Question Category	Response
1	Personal Details	<p>1. Age ? 40 years</p> <p>2. Qualifications: institute and when ? Bachelor of Arts (Honours in Social Work), University of the North, 1988 Bachelor of Arts (Honours in Psychology), University of Pretoria, 1994 Master of Business Engineering, University of Warwick, 2003.</p> <p>3. Years in Eskom ? 12 years</p> <p>4. Years in Enterprises Division and EED ? Not Applicable.</p> <p>5. Title of position currently filled ? Senior Manager (Eskom Shared Services) till the end of the October 2007.</p> <p>New role = Senior Manager (Eskom Skills and Talent)</p>
2	Pre-prepared questions	<p>The questions asked in this segment of the interview are selected as per Table 18 of Appendix 1: List of Questions per Interviewee:</p> <p>1. From your perspective, how large is the engineering skills shortage in Eskom ? From the perspective of Eskom moving into the build programme, there is bound to be a requirement for more skills.</p> <p>From a managerial behavioural and managerial quality point of view, Elsie questions the validity: why is it that we are not absorbing the available engineering skills quickly enough ?</p> <p>Managers want to use the international recruitment drive instead.</p>

	<p>A mandate was given to the Managing Director of Human Resources (Mpho Letlape) to say that we need skills. This is due to skills being identified as a risk in every risk sub-committee in Eskom and engineering as one of those core skills at risk.</p> <p>We get engineers, however they do not look like us e.g a turbine engineer. The manager’s behaviour doesn’t reflect a shortage of skills.</p> <p>You don’t find engineers that are unemployed but there are many that want to join Eskom.</p> <p>The risk of skills has been identified, but the behaviour does not match what is required to close this risk.</p> <p>Elsie provided answers to these 4 questions in one consolidated answer::</p> <ol style="list-style-type: none"> 2. What is Eskom’s current strategy to alleviate this shortage ? 3. What recruitment strategies are in place for engineering skills ? 4. What developmental strategies are in place for engineering skills? 5. What retention strategies are in place for engineering skills ? <p>Eskom has a Resourcing Strategy = 7 B’s.</p> <ol style="list-style-type: none"> 1. Buy: Recruitment from outside. 2. Borrow: Partnerships with other companies e.g skills swapping, but this not being followed since companies are behaving selfishly. 3. Birth: Pipeline i.e. bursars. 4. Build: Development of those inside in Eskom already e.g. IDP and technical programmes i.e John Gosling’s department and Electric Power Research Institute (EPRI) and the Institute of Nuclear Power Organisation (INPO). Secondment to other countries power stations e.g. Hwange in Zimbabwe. EIT in training and mentorship. 5. Boost: Succession management & Retention e.g. enticing
--	--

		<p>financially e.g. retainer bonuses, sign-on bonuses. Talent Manager is a stock market for engineers.</p> <p>6. Bind: Attraction Strategy, according to Deloitte's evaluation Eskom is the second best employer to work for. Image creation and brand marketing even at career expos.</p> <p>7. Bridge: Identified schools (18) that have a need to cultivate so that we get the good product at the end. Winter school with maths and science. Even done at the power stations. We have 70 teachers to further their studies in maths in science.</p> <p>6. What are the KPIs for your area ?</p> <p>7. Which of these KPIs are directly related to the engineering skills shortage issue ?</p> <p>Eskom-wide we have :</p> <ol style="list-style-type: none"> 1. Turnover of core skills (includes engineering) 2. Training days (to support the development) 3. Vacancy Rate 4. Critical, Core and Scarce skills (using the above 3 KPIs) 5. Employee satisfaction i.e. feedback on 15% response rate. <p>Used to do climate survey, but this is too long and costly.</p> <p>8. What interaction do you have with Enterprises Engineering Department (EED) and Training in terms of engineering skills shortage in Eskom ?</p> <p>Direct interaction with Matome and now with Hakiem (hired from London) in terms of CED.</p> <p>Two studies: one from Black & Veatch in terms of detailed skills requirements. The other is an internal report, in which the Eskom University has compiled a report to 2012 in terms of skills requirements versus MegaWatt requirements.</p>
--	--	---

3	Current Interventions	<p>The interviewee’s perspective on the impact of current interventions as listed in Table 2: Description and classification of current interventions</p> <p>Summary is as per Table 14: Summary of Perceived Impact of current interventions undertaken by Eskom. In addition, the following significant comments were made:</p> <ol style="list-style-type: none"> 1. There is a gap in bursars being awarded bursaries without proper skills requirements. Half of the bursaries is merit bursaries in which they do not need to work for Eskom. Elsie suggests that this needs to change to 80% pipeline initiative and 20% community social investment (contributing to AsgiSA & JIPSA) 2. Partnership with Denel (Government initiated) to train and use 100 artisans that Denel were going to retrench. Umsobovu initiative in terms of unemployed graduates. 3. Elsie is excited about the Eskom University as it will enable Eskom to have one view of requirements and view of how much we are investing in training and development. 4. Elsie views Skills Development and Skills Levy as a compliance object with the overall view of skills development in South Africa and contribution to 6% GDP growth. 5. Foreigners are being brought in based on the basis of time limited work permits and with a focus to be in training roles.
4	Alternative Interventions	<p>The interviewee was requested to suggest alternative interventions to those identified in Table 2: Description and classification of current interventions</p> <p>It was suggested that Eskom should realise that:</p> <ol style="list-style-type: none"> 1. We are not going to get the skills that we want immediately and should rather recruit people with a

		<p>view to developing them into what we need.</p> <p>2. In terms of engineering, we need a generic profile of the engineers we need.</p> <p>3. Jimmy Manyi: “Is there a skills shortage or is it the fact that as leaders we don’t see talent ?”</p> <p>4. [Some] engineers in the organisation are pushing paper. We are not using our engineers in the place that they should be.</p>
5	Draft Systems Dynamics Model	<p>The draft systems dynamics model provided in Figure 15 on page 4 was presented to the interviewee. Suggestions for improvement to this systems dynamics model was sought from the interviewee.</p> <p>Expressed that this was a good representation of the problem.</p> <p>Maybe we should go a little earlier in the schooling career e.g. Grade 10.</p>
6	Other Suggestions and Comments	<p>Apart from the guided responses sought from the interviewee on alternative suggestions and improvements to the systems dynamics model, an unguided response was sought from the interviewee on any other suggestions and comments for the author of this dissertation to consider.</p> <p>No further comments.</p>

Table 26 Interview Summary: Elsie Pule

LEADERSHIP AND PROFESSIONAL DEVELOPMENT MANAGER: JOHN GOSLING

#	Question Category	Response
1	Personal Details	<p>1. Age ? 63</p> <p>2. Qualifications: institute and when ? BSc and B. Eng (Electrical), University of Stellenbosch</p> <p>3. Years in Eskom ? 40 years</p> <p>4. Years in Enterprises Division and EED ? Not Applicable.</p> <p>However, John utilised 30 years in the engineering department and was part of the build programme in the 1970s and 1980s. He then spent the subsequent 10 years of his career in capacity building and skills development.</p> <p>5. Title of position currently filled ? Leadership and Professional Development Manager (located within the Human Resources department)</p>
2	Pre-prepared questions	<p>The questions asked in this segment of the interview are selected as per Table 18 of Appendix 1: List of Questions per Interviewee:</p> <p>1. From your perspective, how large is the engineering skills shortage in Eskom ? In terms of Eskom's fundamental business i.e. Operating and Maintenance (O&M), there is a shortage e.g. plant operators. Generation has lost experience to Enterprises Division.</p> <p>In terms of Eskom's build programme, there is a shortage which is related to how we decide to do the work e.g. choice of 38 packages for Medupi Power Station and the level of skill available .</p> <p>Previously had 2500 people when building power stations in the</p>

		<p>1980s. The Electrical and Civil disciplines did all the engineering and got contractors to install. Other disciplines e.g Boiler and Turbine mechanical was essentially ordered as complete packages from suppliers.</p> <p>2. What is Eskom’s developmental strategy for engineering skills ?</p> <p>Pipelining initiative is needed i.e develop people at universities and universities of technology.</p> <p>Attract people into engineering fraternity.</p> <p>However, it takes about 8 years to develop into a productive person after leaving school. There will be a skills gap.</p> <p>We seem to believe that everybody needs a university qualification. However, there needs to be a skills mix and focus them to the work that they have been trained to do. Spoke of previous setup: draughtsman, technicians, technologists and engineers. Need to use people at the right level that they have trained for.</p> <p>Technologists can translate the conceptual designs to the practical designs and can also work at the technician level.</p> <p>Need to develop and focus the people who come out of tertiary education (with a broad area of education).</p> <p>3. What are the key performance indicators (KPIs) for your area ?</p> <p>4. Which of these KPIs are directly related to the engineering skills shortage issue ?</p> <p>We do not have adequate skills needs analysis. We should have both manpower plans (numbers) and skills plans (competencies and level of skill). We are not very good at putting these plans together.</p>
--	--	---

		<p>EED has a manpower number and qualification requirements, however we have not produced a skills plan (what competencies are required).</p> <p>John was part of establishing Eskom Enterprises as a means to house and retain the skills that would have been lost since we were not in a build programme. However, the eventuality was that we still lost some skills due in part to a change in the top level management.</p> <p>Example of American Power Utility Tennessee Power which ran a comparably sized power grid in relation to Eskom but ran the utility with just 12000 people by utilising outsourcing (versus Eskom's ~80000 in the 1980s and ~32000 at present). Now they have a problem that most of their current staff are at retirement age (with no replacements available).</p> <p>5. What interaction do you have with Enterprises Engineering Department (EED) and HR in terms of engineering skills shortage in Eskom ?</p> <p>John forms part of HR. In terms of the Eskom University, there is some interaction with ED (identifying what ED's needs are). In terms of the need for technical skills, we haven't really defined this as yet.</p> <p>Meeting with Black & Veatch to determine what their skills development capabilities are and this forms part of a process of looking at the Eskom University.</p>
3	Current Interventions	<p>The interviewee's perspective on the impact of current interventions as listed in Table 2: Description and classification of current interventions</p> <p>Summary is as per Table 14: Summary of Perceived Impact of current interventions undertaken by Eskom. In addition, the following significant comments were made:</p> <p>1. Local Recruitment drive is positive. However, the</p>

		<p>foreign recruitment drive is negative.</p> <ol style="list-style-type: none"> 2. Mentorship and Development: Very bad. ECSA has been very critical of Eskom's training programme. Focus needed here. 3. Mentioned that there is the false perception in the organisation that the engineering system to be implemented will replace the need for more engineers. In fact, the amount of people needed to support this system is higher than how we engineer now. 4. Partnerships with other companies were either negative or neutral. 5. GARP & TASK: Eskom goes through cycles: from broad band to narrow band and now back to a narrow band structure. Narrow-banding needs a lot of maintenance but does have advantages. 6. Bursary programme: Eskom is a leader in this field. However, when coming into Eskom, we do not induct the people into the organisation in a welcoming way. Must be kept at a strategic level, but get the requirements from operational level. Otherwise, organisation's long term needs will not be met. Must take into account global and national skills market trends. Academic sustainability must be looked at as well. 7. The Eskom Univerity is an Eskom corporate university. It will cover from apprentices through to executive development. It will work with other State Owned Enterprises (for now). Joint ventures (JVs) with other companies e.g. Stainless Steel Association, Sasol etc will be pursued. 8. John spoke of Sasol bringing in 2000 Taiwanese and the Eskom's OCGT with the Irish. He considered this as negative.
--	--	--

4	Alternative Interventions	<p>The interviewee was requested to suggest alternative interventions to those identified in Table 2: Description and classification of current interventions</p> <p>It was suggested that Eskom should pursue the following interventions:</p> <ol style="list-style-type: none"> 1. Retaining what we have. 2. Mentoring: Proactive approach i.e. young people should be attached to mentors as “shadows” 3. Overseas training must be stepped up. John suggested 40 to 50 people. 4. Delivery of training i.e. e-learning and much broader base in the organisation. 5. Making people feel welcome and important to the organisation. 6. Dedicated Instructors: for the training of the engineering graduates.
5	Draft Systems Dynamics Model	<p>The draft systems dynamics model provided in Figure 15 on page 4 was presented to the interviewee. Suggestions for improvement to this systems dynamics model was sought from the interviewee.</p> <p>In Eskom (SAP HR database) there are 1025 engineers.</p> <ol style="list-style-type: none"> 1. Sending people to other industries (and overseas) and utilising their mentorship capability. 2. Bolstering our national academic support.

6	Other Suggestions and Comments	<p>Apart from the guided responses sought from the interviewee on alternative suggestions and improvements to the systems dynamics model, an unguided response was sought from the interviewee on any other suggestions and comments for the author of this dissertation to consider.</p> <p>The R3,5 billion SETA skill development fund should be utilised to bolster the upfront feedstock (i.e. maths and science at schools).</p> <p>A national policy can have a massive impact on the country e.g. India with IT sector and Ireland (industry working with higher education).</p>
---	--------------------------------	--

Table 27 Interview Summary: John Gosling