

UNIVERSITY OF KWAZULU-NATAL

**An investigation into the statistics of professional civil engineers and
the demand and supply of professional female civil engineers in South
Africa is realistic.**

By

Avana Dilrajh

206501925

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requirements for the degree of
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College of Law and Management Studies**

Supervisor: Dr Pfano Mashau

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DECLARATION

I, Avana Dilrajh declare that:

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Signed:

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ABSTRACT

This research investigated the registered professional engineers' statistics in the South African context. Thereafter, an in-depth discipline specific exploration of the number of graduate civil engineers produced during 2001-2014 from four (4) leading universities in South Africa was undertaken. Differences between the gender statistics, with regards to graduates and time frames taken to register as a professional civil engineer, were determined in conjunction with ratios developed for forecasting. Evaluation of graduate civil engineers transitioning into professional engineers is important and necessary to benefit the country in order to establish if the supply is adequate.

With the current gender empowerment goals implemented by government, many organisations are left with an urgent need to fill positions with registered female civil engineers but are finding this difficult. The knowledge and experience gained from this study has resulted in a better understanding of the lack of professional engineers with emphasis in the civil engineering sector and female representation in South Africa. The demand and supply of female engineers is very unbalanced and with the current trends that have been formulated, the ability to fulfil these demands worsen with time unless measures are implemented to alleviate the situation going forward. It was the intention of the author that this research be viewed as a preliminary investigation, which could be used to assess the viability of launching more comprehensive investigations on this topic.

Key Words:

Engineering, Civil Engineer, Female, Demand and Supply

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CHAPTER 1 : INTRODUCTION TO THE STUDY

1.1 General Overview

By the middle 19th century, two disciplines of engineers existed namely, military and civilian engineers (Merritt, 2015). Originally civil engineers were known as civilian engineers and were accountable for the majority of the engineering projects which included designing, organising and managing the construction of a country's sanitation systems, railways, buildings, structures, roads, ports and water supply (Vardhan, 2016) .

After the industrial revolution which resulted in the high demands for the proliferation of machines, there was a need for specialised engineers, i.e. mechanical engineers who designed and manufactured these machines (Trevelyan, 2014). Thereafter the developments of electric machines subsequently resulted in another discipline of engineering known today as electrical engineering (Chumakov, 2014). Chemical engineering was developed in the early twentieth century followed by computer/software engineering in the late twentieth century and so forth with many other branches of engineering being distinguished with time (Trevelyan, 2014).

Civil engineers practice in the public realm, requiring detailed interface with public decision-making, including dealing with multiple stakeholders; socioeconomic factors, public policies, laws, and regulations, financing, environmental considerations, and other factors (Elms & Brown, 2012). All of this takes place in an increasingly open and transparent environment, requiring more advanced communication and broad professional practice skills (Diloreto, 2013).

The CECB (Committee on Engineering Capacity Building) of the WFEO (World Federation of Engineering Organisations), has highlighted the fact that the world is in dire trouble when it comes to taking care of its' infrastructure and hence providing for its ever increasing growing population (Botha, 2014). Lawless (2011, p.36) poses an interesting question: "Isn't the quality of life seemingly something that is more important and has the implication of greater

concern to a mother because of her consideration for her offspring, rather than that to the father?”. If so then why are there such a small amount of female engineers (Lawless, 2011).

Throughout history, men have always outnumbered women significantly in the science and engineering sector (Koprowski, 2016). The disparity has narrowed only modestly whereas the demand for female engineers has increased significantly (Verity, 2013). Stepping back into the origins when men were hunters and women were tasked with organising the home (cave), women were also assigned with encouraging communication with their kids, creating an environment conducive of learning and extending this to the tribe as well (Merritt, 2015). Building on this, whilst men were structured to be founded on hierarchical order, requiring male dominance to prevail, the women were team workers who considered others predominantly as parallel equivalents (Lippa et al., 2014). It shows the excellent negotiating skills and calibre that women naturally exude which can be utilised to channel the engineering sector forward (Kathleen et al., 2013).

1.2 Literature Review

A broad summary of this quantitative study included a brief overview of the engineering industry with emphasis into civil engineering. Insight into the associated qualifications that can be pursued in the civil engineering sector was provided, highlighting any differences corroborated. Factors such as prerequisite requirements, cost of studies, duration and course content was distinguished. This resulted in the investigation of progression into professional status and governing statutory bodies in engineering with emphasis in civil engineering. Further exploration into civil engineering included work sector differentiation; professional statistics of total engineers and civil engineers was investigated. Differences between professional engineer gender statistics were highlighted where applicable. Factors affecting these statistics were subsequently investigated. International professional practices were included and this therefore, allowed for incorporation of expert knowledge as a means of placing the research in context.

1.3 Motivation for the study

With the continuously growing population in South Africa, there arises a need for more planning and infrastructure to provide for this growth (George et al., 2016). The lifespan of humans has doubled since the first half of the twentieth century and this astounding increase is mostly attributable to the technology that engineers have produced (Warren, 2015). These advances have resulted in a magnanimous improvement in the provision of basic infrastructure including roads, clean air, sanitation, clean water, water-borne sewerage systems, transport, housing and provision of electricity (Mitchell, 2017). Globally it was found that engineers are one of the hardest positions to fill (Newswire, 2016). The practice of civil engineering differs from many other disciplines of engineering and created the foundation for those disciplines (Clawson, 2014). According to Johnson (2013) there is a rapid growing need for civil engineers. Both local and international research has shown that municipalities within South Africa have very low civil engineering expertise and capacities to sufficiently deliver, manage and maintain their infrastructure sustainably (Lawless, 2017).

What is the status quo with regards to transfers of both candidate engineers and candidate civil engineers into professional status in South Africa?

This study provides insight and knowledge for the engineering industry and South African skills requirements.

The specific audiences that will benefit from this study include:

- Professional engineers
- Graduate civil engineers
- Engineering Council of South Africa (ECSA)
- Participating ECSA accredited universities
- South African citizens

1.4 Problem Statement of the study

South Africa is faced with a shortage of engineers to appropriately service the country (Bhorat et al., 2014). There is unknown statistics for graduate

engineers, candidate engineers and timeframes for conversion into professional status to enable the country to plan accordingly. This coupled with updated employment equity targets, creates the purpose of this study.

1.5 Aims and objectives of the study

The aim of the study was to determine the current statistics of professional engineers and to synthesise and critically interrogate the 2001-2014 graduate and professional civil engineer statistics. Cross examination into well performing universities was done via comparative studies analysis. Timeframes needed to convert to professional status was investigated together with gender comparisons.

The objectives of the study are:

- To investigate the process of how candidate engineers transfer to professional status and to examine the professional engineer statistics.
- To establish the graduate civil engineer statistics from 2001-2014.
- To determine the professional civil engineer statistics from 2001-2014.
- To establish time frames (trends) relating to conversion from candidate civil engineer (graduate) status to professional status, henceforth highlighting gender and university based differences.
- To highlight gender equality standards/requirements and forecast any trends to achieve these requirements.

1.6 Research questions

- What are the current professional engineer statistics in South Africa?
- What are the statistics of graduate civil engineers from 2001-2014?
- What are the statistics of professional civil engineers from 2001-2014?
- What are the time frames related to the conversion of candidates (graduates) to professional civil engineer status with gender comparisons as well as per accredited university?
- What are the updated trends, requirements and recommendations for future planning to address the demand of civil engineers?

1.7 Research Methodology

This archival research study concentrated on the demand and supply of professional civil engineers in South Africa. In this study, background information regarding the process of registration to professional status was provided. A quantitative research design was used for this study. The statistical data explored the current number of professional engineers registered on the Engineering Council of South Africa's (ECSA) database. Subsequently, an investigation into the statistics of graduate and professional civil engineers in South Africa was undertaken to give foresight into the number of females in the industry with comparisons to male counterparts throughout 2001 to 2014. The reason for collecting quantitative data was for a valid deduction of statistics to provide adequate analysis into the interpretation and knowledge on the supply of professional civil engineers. Graduated civil engineers' statistics was captured from records provided by four (4) Engineering Council of South Africa (ECSA) accredited universities. Names of graduated civil engineers were checked on ECSA's database to confirm which category they are registered in. If they obtained professional registration, their registration date was captured to calculate the time frames taken to transfer into the professional category. A comparative analysis of gender statistics was compiled. Ratios were formulated showing the differences in statistics and the number of years taken to achieve professional status. In addition, accredited universities were compared to show realistic registration time frames and graduate production rates.

1.8 Delimitations and Assumptions

Haegele &Hodge (2015) describe assumptions as a set of defined beliefs that assist in guiding a researcher's approach to their investigations. Helmich et al. (2015) recognises that whilst researchers treat assumptions as possible limitations, it is also seen as unspecified uncertainty. To counterbalance this effect, provision of alternatives or reasoning into the potential impact caused by the assumptions must be deduced (Helmich et al., 2015). Simon (2013) defined a delimitation as a result of specific choices that a researcher makes. It is the boundaries proposed for the research (Hancock & Algozzine, 2016).

The ensuing delimitations and assumptions that were found in this study were:

- It was assumed that the engineers in the statistics are working within the engineering sector and within South African borders. This assumption was offset by utilising the Engineering Council of South Africa's database which exhibits registered engineers within South Africa.
- A limitation was inconsistent archival data and the lack of provision of archival data from all of the accredited ECSA universities. This limitation was reduced by utilising averages, standard deviation and provision of ratios deduced from available data.
- Due to time constraints, only civil engineering graduates were investigated at the accredited universities and within a specific time frame from 2001-2014. This provided the study with a higher accuracy of results since only one discipline was concentrated on and the timeframe was extensive.

1.9 Structure of the study

This study consists of six (6) chapters as detailed:

Chapter 1 (*Introduction*) provided a brief background into the context of this study, explaining the fundamentals of this study as well as outlining the research questions and objectives that relate to the research topic.

The aim of Chapter 2 (*Literature Review*) was to analyse and discuss current literature associated with the research question and to integrate expert knowledge into the research that was undertaken. This chapter focused on the conversion of candidates to professional status and associated aspects of doing so. Current statistics were discussed and relevant summaries were drawn in conjunction to international standards.

Chapter 3 (*Methodology*) covered the methodological approach and procedure undertaken for this research. The methodological approach was

analysed and explained hence justifying appropriateness for this study.

Chapter 4 (*Results*) presents the results/findings of the archival research as well as an interpretation, analysis and refinement of these results.

Chapter 5 (*Discussion of results*) provided an in-depth comparative analysis and subsequent discussion corresponding to the results derived from the literature review and findings. Important aspects pertaining to the aims and objectives were highlighted and explained.

Chapter 6 – (*Conclusion and recommendations*) briefly outlined the important factors that were accounted for in the research methods utilised to produce the full achievement of aims and objectives. These recommendations serve to aid key stakeholders in effectively attending to the supply and demand required for engineers and preventing a repetition of the mistakes (if any) encountered previously.

1.10 Conclusion

The baby boomers generation (Mid 1940 – 1964) resulted in the engineering sector being principally male subjugated as households predominantly consisted of the men studying and working (Green, 2017). Now with the rise of generation X and Y (1965-2001), recent demands in professional female engineers have become harder to achieve (Berkup, 2014). The scope of the study had to be narrowed to include only civil engineering since there are numerous disciplines within engineering and time constraints proved to be a hindrance for inclusion of all disciplines into one study. Adequate research into the civil engineering discipline is deficient and the literature review provided a means to explore all associated links to professional engineer statistics and prove the deficiency.

CHAPTER 2 : LITERATURE REVIEW

2.1 Introduction

Engineering is a profession that is required in all facets of life (Adogbo et al., 2015). Civil engineers are entrusted as leaders that devise solutions which assist in guiding communities and countries towards economic growth with cognisance of sustainable development (Diloreto, 2013). This chapter focused on the definition of engineers with particular emphasis on the civil sector and discussed the process of registering as a professional engineer. It looked at the required targets in comparison to international standards with relation to the demand and hence focused on the supply of professional engineers. Areas of concern surrounding the reasons for the lack of engineering statistics were investigated and relevant summaries were drawn with inclusion of any gender partialities.

The goal of this chapter was to critically analyse and discuss literature pertaining to the research question and to integrate this knowledge within context.

2.2 Growth of the engineering profession and associated acts

The first group of professional individuals were established thousands of years ago when the guilds were initiated by the masons (Lipson, 2015). The British society in the eighteenth (18th) century saw the development of the Freemasonry being accepted as an institution classing or force (Clawson, 2014). This development dates further back to the seventeenth (17th) century when Scottish and English men began requesting admission into lodges where practising stonemasonry was undertaken (Bogdan & Snoek, 2014). Thus began the masonic system which was distinguished by its class diversity and social prestige with the idealised status of being a “Master Mason” at the top of the ranks (Dumenil, 2014). In the nineteenth (19th) century there were fraternal agents that would sell lodge memberships (Clawson, 2014).

South Africa’s engineering history began in 1892 when the first train entered Johannesburg and within the same year, in June 1892 the South African Association of Engineers and Architects was formed thus becoming the first professional body for engineers (Hyslop, 2016). Subsequently, in 1902 this organisation was changed to

the South African Association of Engineers (Sperotto, 2015). An engineer's certificate of competency was then required once the Transvaal Colony's legislative council passed an amendment in 1903 to assist in the regulation of the engineering profession (Sperotto, 2015).

South Africa's engineering cadres followed the British prototype and by 1968 the implementation of the Professional Engineers Act 81 of 1968 commenced (COET, 2017). The control, registration, reservation and discipline of engineering work was regulated by the representing councils (Nel, 2012). All members had to have the prerequisite engineering educational credentials and ensured that the interest of regulation and public safety was adhered to (COET, 2017).

By 1984, there were approximately twenty-four (24) voluntary organisations and four engineering statutory bodies, the Board of Control for Engineering Technicians, Board of Control for Engineering Technologists, Board of Control for Certificated Engineers and the South African Council for Professional Engineers (COET, 2017). These four (4) statutory bodies were then replaced by the Engineering Council of South Africa (ECSA) on the 13th of July 1990 (UKZN, 2017b). In 2001, the Engineering Professions Act. 46 of 2000, replaced the former and is currently being adhered to. The Act defines and explains all related factors concerning the engineering profession. It stipulates the power of ECSA with regards to categorising all associated engineering qualifications, fees, charges, educational accreditation, committees, funds and general power extents (EPA46, 2000). It also covers all aspects of registration, authorised titles, cancellation, renewal requirements, professional conduct, and grievances amongst the other binding law enforcements (EPA46, 2000).

2.2.1 Categories of civil engineering qualifications

There are various institutions that provide engineering undergraduate qualifications ranging from national diplomas, bachelor of technology, bachelor degrees and honours degrees. Each category is explained in Table 2.1.

Table 2.1: Categories of civil engineering qualifications with related institution ((DUT, 2017c, UCT, 2017)

Programme Type:	Institution:	Profession title:
Bachelor Degrees: BEng, BSc(Eng) or BIng ("BEng-type")	University	Engineer
Bachelor Of Technology: (BTech)	University of Technology / Distance education institutions	Technologist
National Diploma : (NDip) / Bachelor of Engineering Technology in Civil Engineering: (BEng Tech Civil) (Pending approval)	University of Technology / Distance education institutions/ College	Technician

The focus of this study will be on university institutions as an in-depth study into all institutions cannot be fulfilled due to time constraints and the hierarchical order highlights the greater significance of professional engineers in relation to those of professional technologists and technicians (Carroll, 2017). Further explanations explicating the differences between them are provided in Section 2.2.2.

2.2.2 Differences between acquiring a degree and acquiring a technical qualification in civil engineering

There are various differences between attaining a degree from university as opposed to studying from other intuitions, which include:

2.2.2.1. Level of Qualification

The most rudimentary difference between gaining a university degree as opposed to a technical engineering course that produces a diploma or national certificate will undoubtedly be the qualification level that you obtain. A brief breakdown of the South African National Qualification Framework (NQF) shows the ranking of each qualification in Table 2.2 (SAQA, 2015):

Table 2.2 : Showing the subframeworks and qualification types.

Adapted from SAQA (2015)

NQF LEVEL *	DESIGNATION:
1	National Certificate level 1

(Continued)

NQF LEVEL*	DESIGNATION:
2	Elementary Certificate level 2
3	Intermediate Certificate level 3
4	National Certificate level 4
5	Higher National Certificate
6	Diploma and Advanced Certificates
7	Bachelor's Degrees and Advanced Diplomas
8	Bachelors Honours Degrees, Postgraduate Diplomas and Professional Qualifications
9	Master's Degree / Master's Degree (Professional)
10	Doctoral Degree/Doctoral Degree (Professional)

2.2.2.2. Course Content

An engineering degree is often exceedingly more scientific, theoretical as well as academic. Whilst an engineering technical course typically focuses on educating students on practical applications (Odendaal, 2016). The new course (pending approval) for the bachelor of engineering technology in civil engineering has 420 credits from DUT (DUT, 2017a). The Bachelor in Civil Engineering (Honours) from UKZN has 576 credits with no less than 96 credits that should be equivalent or above Level – 4 (UKZN, 2017a).

2.2.2.3. Specialisation

With a civil engineering degree, the graduate can specialise in several or all of the diverse disciplines in the profession. These include; transportation, urban engineering, project management, material technology, construction, structural engineering and water management (Mitchell, 2017). This affords civil engineers the ability to work in a variety of settings such as; design consultancies, state agencies, construction sites and government departments throughout their career (UCT, 2017).

Obtaining a technical certificate or following a diploma programme, will result in a more specialised and unique qualification in a specific engineering field (Odendaal, 2016). This is also noted when choosing to begin postgraduate studies since an aspiring technologist has to decide on a particular specialist field of engineering they

will work in. The requirements for acceptance to complete their BTech: Engineering: Civil is a National Higher Diploma in Civil Engineering, one year related experience in the field they want to specialise in, three years general civil engineering experience and will have to have passed the following subjects in order to choose the specialist field as described in Table 2.3 below (DUT, 2017b):

Table 2.3: Five specialist fields applicable to BTech studies in civil engineering
Adapted from DUT (2017)

Specialist field attaining BTech in:	Prerequisite subjects:
Construction Management	Theory of Management (IV) or equivalent.
Geotechnical	Soil Mechanics (T4) and Engineering Geology (T2)
Structural	Theory of Structures(T4) and Structural Design (T4)
Transportation/Urban	Road & Rail Construction and Design (T4) and Civil Engineering Documentation (T4)
Water	Water and Waste Water Engineering (T4)

2.2.2.4. Completion Time

The minimum completion time for an engineering degree is 4 years or 8 semesters of full-time studying (UKZN, 2017a). In addition, BScEng candidates must complete a minimum of 14 weeks' vacation / practical work (UKZN, 2017a). Since 2014, the engineering students must also pass ZULN101 (Basic isiZulu language studies course) or obtain credit for this course for completion of their qualification (UKZN, 2017a).

The minimum completion time for a diploma in civil engineering is 2 years and a period of 25 weeks for experiential learning is mandatory for completion of this qualification (DUT, 2017a).The new bachelor of engineering technology in civil engineering that has been offered since 2017, is a 3 year course with no vacation / practical work necessary for completion of the qualification (DUT, 2017a).

2.2.2.5. Places of study

An engineering degree can only be achieved at a university (Kloot & Rouvrais,

2017). However, completion of a technical qualification can be accomplished at various different institutions, such as technical universities otherwise now known as universities of technology or Technical and Vocational Education and Training (TVET) colleges as well as private distance colleges (e.g. INTEC College, Oxbridge Academy, UNISA, Damelin College) (Odendaal, 2016).

2.2.2.6. Affordability

A brief breakdown of the differences in costs to pursue either a degree or diploma is seen in Table 2.4 (DUT, 2017a, UKZN, 2017b):

Table 2.4: Showing the differences in costs for completing a degree at UKZN and a diploma at DUT

Year	1	2	3	4	Total
UKZN	R 39 320.00	R 39 320.00	R 39 320.00	R 39 320.00	R157 280.00
Semester	1	2	3	4	Total
DUT	R 16 510.00	R 17 610.00	R 18 900.00	R 22 110.00	R 75 120.00

This excludes costs for residence fees, meals and books. According to UKZN (2017b), fees typically rise annually according to inflation. Due to the UKZN student fee guide's lack of differentiated annual fees for studying civil engineering, conforming to ceteris paribus allowed the utilisation of the same fee for the entire degree duration. Durban Institute of Technology (DUT) however provided the current fees for the various semesters and provided for a more accurate estimation for their diploma qualification (DUT, 2017c).

2.2.3 University entrance requirements

The minimum requirements for entrance into university to pursue a career in Civil Engineering is a South African National Science Certificate inclusive of a Bachelors pass together with the minimum following criteria (UKZN, 2017a):

- Both Physical Science and English must be of level 6 points which is 70-79%.
- Life Orientation must be of level 6 points which is 50-59%.

Three other subjects approved for studying a degree which is stated in CAO (2017) as designated subjects are found in the table below:

Table 2.5: Understanding the Programme Choice List
Adapted from CAO Handbook Entry 2017 (2017, page16),

Designated Subjects:		
Accounting	Economics	Life Sciences
Agricultural Science	Engineering Graphics & Design	Music
Business Studies	Geography	Visual Arts
Consumer Studies	History	Religion Studies
Dramatic Arts	Information Technology	
Languages (one language of learning and teaching at a higher education institution and two other recognised language subjects)		

The other alternative for entrance into a university is a matriculation exemption together with maths and physical science with a 'C pass' in higher grade level.

Sinha (2015) the executive dean of the Faculty of Engineering and Built Environment at the University of Johannesburg, states that there is a substantial number of university drop outs within the engineering faculty during the initial two years of studying (Businesstech, 2015). She also indicated that by the fourth year of specific technical disciplines, there were as little as ten (10) per cent of the original students that began in the first year group who graduate from South Africa's universities (Businesstech, 2015). Provision of civil engineering specific statistics in this regard was difficult to attain from existing literature.

2.3 Criteria for professional status

Engineering Council of South Africa (ECSA) is a legal entity that was established based on the terms as stated in the Engineering Profession Act (EPA), 46 of 2000 (Sperotto, 2015). ECSA regulates the engineering profession within the borders of the Act (EPA46, 2000). It assesses and accredits educational engineering programmes and the registration of qualified engineers who are beginning their careers as well as professionals in each specified category (Maupa, 2015). ECSA is

authorised by the Engineering Profession Act, to evaluate if institutions that conduct engineering programmes, can be recognised and given accreditation, by means of regular visits (Mutereko, 2017). The current accredited universities include the University of Cape Town(UCT), University of KwaZulu-Natal (UKZN), University of Pretoria (UP), University of Witwatersrand (WITS), University of Johannesburg (UJ) and the University of Stellenbosch (US) (ESCA, 2017).

The type of qualification achieved in tertiary level depicts the category of professional registration status, methods and criteria for acceptance by ECSA. This is detailed in Table 2.6.

Table 2.6: Registration requirements and related titles

Adapted from ECSA (2016)

Programme Type:	Meets Educational Requirements for Registration as:
BEng, BSc(Eng) or BIng ("BEng-type")	Candidate Engineer, Professional Engineer
BTech	Candidate Engineering Technologist, Professional Engineering Technologist
National Diploma	Candidate Engineering Technician, Professional Engineering Technician

Typically a candidate requires a stipulated number of years of post-graduate experience that fulfils the criteria and required outcomes which ECSA have established as sufficient for professional registration (Maupa, 2015). Each educational programme type lends itself to a different set of outcomes and registration methods by ECSA. A typical difference will be the presentation and personal interview panel that candidate engineers have to pass in order to progress to professional status over and above their experiential report fulfilling the requirements (Krige, 2017). There is a minimum of three years post graduate experience that is required in order to apply for professional engineer status (Lawless, 2017). These three years must encompass all outcomes as required by ECSA, in terms of design, construction supervision and project management in the following categories (ESCA, 2017):

- Group A - Engineering Problem Solving

- Group B - Managing Engineering Activities
- Group C - Impacts of Engineering Activity
- Group D - Exercise judgement, take responsibility and act ethically
- Group E - Continuing Professional Development

The foremost difference between a Professional Technologist and a Professional Engineer is that a Professional Technologist is required to specialise in a specific discipline of engineering, whilst an Engineer has the education consisting of a broader variety of subjects (DUT, 2017c). This further reiterates that engineers are at the top of the hierarchy order showing their prominence in the industry (Carroll, 2017). Whilst ECSA stipulate the minimum requirements for registration as a professional, the average time take for this registration is unknown. This highlights a gap in the literature.

2.4 Governing statutory bodies in civil engineering

2.4.1 Engineering Council of South Africa

ECSA's principal function is the control and regulation of all engineering professions in regarding this EPA Act (Sperotto, 2015). ECSA's core functions include the (ECSA, 2016):

- accreditation of all engineering programmes,
- registration of persons as candidates once graduated,
- registration of candidates as professionals in their specified categories,
- revision and regulation of the engineering practice of all registered persons,
and
- monitoring and ensuring adequate continuous professional development.

Subsequently, ECSA is the sole organisation in South Africa which has the authorisation to register all disciplines of engineering professionals and to ensure the code of ethics is adhered to (Legoabe & Worku, 2017). ECSA is the only statutory body that can bestow the usage of all engineering titles on those persons who meet the professional requisite registration standard (ECSA, 2016). The titles include Professional Engineering Technologist (Pr. Tech Eng.), Professional Engineer (Pr. Eng.), Professional Certified Engineer (Pr. Cert Eng.), Professional Engineering

Technician (Pr Techni Eng) (ECSA, 2016). The overarching act followed by engineering professionals, the Engineering Profession Act (No 48 of 2000) does not legislatively make it mandatory that every graduate and/or professional must register with the statutory council ECSA (EPA46, 2000). Subsequently there is no pre-condition required when undertaking engineering related work within South Africa. This causes a tandem effect resulting in challenges faced in the control of the profession's regulation and allows those not registered with ECSA, the freedom to follow their own jurisdiction.

2.4.1.1 Associated Fees

ECSA's current application and annual fees applicable from 1 April 2017 to 31 March 2018 is seen in the tables below as adapted from ECSA (2017):

Table 2.7: Indicating the application fees for acceptance into ECSA various categories

APPLICATION FEES (VAT INCLUDED)		
Candidate Engineers	Within one(1) year obtaining a qualification recognised by ECSA for the purposes of candidate registration: R 700.00	Later than one (1) year subsequent to obtaining a qualification recognised by ECSA for the purposes of candidate registration: R1 750.00
Foreign Qualification Assessment	R1750.00	
Professional	For applicants who have uninterrupted candidate registration: R3 500.00	For applicants who are not registered as a candidate or the other available candidate categories: R6 990.00

Table 2.8: Specifying the annual fees to be paid by the persons in the various ECSA categories

ANNUAL FEES (VAT INCLUDED)		
Candidates	Partial Exemption R 1 274.00	No Exemption R 1 461.00
<ul style="list-style-type: none"> Individuals that are registered in any of the candidate categories for greater than six (6) years, will have to pay the equivalent annual fees of those individuals registered within the professional and registered category. 		
Professional and Registered Categories	Partial Exemption: R 3 072.00	No Exemption: R 3 627.00

2.4.1.2 Engineering disciplines managed by ECSA

ECSA oversee all associated accreditations of universities, candidate and professional registrations as well as legal implication inferences for the following engineering specific disciplines ECSA (2016):

- Aeronautical Engineering
- Mining Engineering
- Chemical Engineering
- Industrial Engineering
- Electrical Engineering
- Mechanical Engineering
- Agricultural Engineering
- Metallurgical Engineering
- Civil Engineering

2.4.1.3 Continuing professional development

Professional engineers are required to ensure that they adhere to fulfilling the CPD, better known as the Continuing Professional Development mechanism that ECSA have established to ensure continual increase in skills and competency (Muller, 2015). A registered person is only allowed to have their registration renewed if they “apply” in accordance with the Engineering Profession Act of 2000 (Act 46, 2000, Section 22(1)) (EPA46, 2000).

Every 5 year cycle commences on the date of registration as shown on their registration certificate as issued by ECSA (Schoeman & Robinson, 2014). Subsequently, this date constitutes the end of their cycle after 5 years and is deemed their expiry date which requires renewal of their registration (ECSA, 2017a).

The CPD mechanism ensures that all registered persons are informed and up-to-date with cutting-edge changes and information including improvements and the latest concepts (McDiarmid, 2015). This is achieved by obtaining a minimum of 25 credits throughout their 5 year cycle. These credits are attained on a category basis as adapted from ECSA (2017a):

- Category 1: Credits achieved for developmental activities – via attending validated developmental or structured activities for example congresses, conferences, large group workshops and the like.
- Category 2: Credits achieved for work-based activities – through performing day-to-day engineering associated work as well as from mentoring candidate engineers.
- Category 3: Credits achieved for individual activities – such as attaining membership to any of ECSA's recognised voluntary organisations as stated in 2.5.1.4 and undertaking other activities that are related to engineering.

At least 5 credits must be aligned with developmental activities (Category 1) as a further distinguished requirement. within Category 1 for developmental activities (ECSA, 2017a). In addition the registered person must attain a yearly complement of minimum 3 credits (ECSA, 2017a).

2.4.1.4 Voluntary associations

ECSA has acknowledged various voluntary associations who applied to be recognised in accordance with section 36(1) of the EP Act and has subsequently accepted the following organisations as per Section 25 (3) of the act under Schedule A (ECSA, 2016):

- Aeronautical Society of South Africa (AeSSA)
- Association of Mine Managers of South Africa (AMMSA)
- Association of Mine Resident Engineers (AMRE)
- Clinical Engineering Association Of South Africa (CEASA)
- Concrete Society of Southern Africa (CSSA)
- Institute of Electrical and Electronic Engineers South African Section (IEEE)
- Institute of Professional Engineering Technologists (IPET)
- Institution of Certificated Mechanical and Electrical Engineering (ICMEESA)
- Institution of Municipal Engineering of Southern Africa (IMESA)
- International Council on Systems Engineering (SA Chapter) (INCOSE SA)
- Lift Inspectors Association of South Africa (LIASA)
- National Society of Black Engineers (NSBE)
- Society For Asphalt Technology (SAT)

- Society of Telkom Engineers (STE)
- South African Colliery Engineers' Association (SACEA)
- South African Colliery Managers Association (SACMA)
- South African Institute of Agricultural Engineers (SAIAE)
- South African Institute of Electrical Engineers (SAIEE)
- South African Institute of Marine Engineers and Naval Architects (SAIMENA)
- South African Institute of Refrigeration and Air-Conditioning (SAIRAC)
- South African Institution of Chemical Engineers (SAIChE)
- South African Institution of Civil Engineering (SAICE)
- Southern African Asset Management Association (SAAMA)
- Southern African Institute for Industrial Engineers (SAIIE)
- Southern African Institute of Mining And Metallurgy (SAIMM)
- The Chamber of Engineering Technology (COET)
- The South African Institution of Mechanical Engineering (SAIMechE)
- South African National Committee on Large Dams (SANCOLD)
- South African Society for Railway Engineering (SASRE)
- Lifting Equipment Engineering Association of South Africa (LEEASA)
- Consulting Engineers of South Africa (CESA)

Since the main discipline under consideration in this study is civil engineering, only those voluntary associations will be elucidated. A few other organisations that civil engineers can subscribe to, but is outside the borders of this study, include the Institute of Professional Engineering Technologists and the National Society of Black Engineers (STE). Many of the voluntary organisations provide benefits ranging from discounted ECSA fees, CPD points for attending meetings, updated information pertaining to technological advancements and the like (Kriel, 2013).

2.4.2 Concrete Society of Southern Africa NPC

CSSA is the concrete society of Southern Africa (CSSA, 2017). It is a voluntary non-profit association aimed at promoting innovation and excellence in every aspect of the usage of concrete and any related services and associated products (CSSA, 2017). Similar to SAT, they provide a conduit for networking and the transfer of technological advancements between their members and any international and local

affiliates (Businessstech, 2015). One of the mentionable affiliates is the American Concrete Institute who plays a vital role in aiding South Africa's global integration (CSSA, 2017).

2.4.3 Institute of Municipal Engineering of Southern Africa

Inaugurated in 1961, IMESA (Institute of Municipal Engineering of Southern Africa) promotes the development and expansion of best practice knowledge within the local government municipal community (IMESA, 2017). It comprises of a diverse range of members including municipal engineers, various companies and represents numerous Southern African countries (IMESA, 2017).

2.4.4 Society for Asphalt Technology

The Society for Asphalt Technology, otherwise known as SAT, was established in 1994 and is concerned with the provision of both professional and technical expertise in every aspect of the manufacturing and usage of bituminous and asphalt products (SAT, 2014). SAT also endeavours to ensure that there is an active association between local and global professional bodies/practitioners thereby keeping abreast of the latest international developments (SAT, 2014). SAT has even established their own constitution which can be downloaded from their website.

2.4.5 South African Institute of Civil Engineering

The South African Institution of Civil Engineering is an organisation aimed at advancing the professional knowledge and improving the practice of the civil engineering discipline (Kriel, 2013). SAICE's mission includes striving as adapted from SAICE (2017):

- to continuously be a learned society,
- to enable their members by means of accountability and consultation, to provide economically and environmentally sustainable infrastructure Consulting Engineers of South Africa (CESA)
- to create an effective means to channel the needs and interest of their members by ensuring a stable, strong and dynamic organisation,
- to ensure that there are continuous professional development courses provided to their members in communication, technical and managerial skills,

- to uphold and enhance the professional code of ethics practised in the civil engineering discipline,
- to ensure the enhancement of the recognition, respectability and desirability of the civil engineering profession,
- to encourage their members to continuously strive for quality and excellence in their industry.

2.4.6 Chamber of Engineering Technology

The Chamber of Engineering Technology was established in 1984 and has been through many name changes and transformations however throughout these vicissitudes, this voluntary organisation has continued to be widely involved in all types of engineering matters (COET, 2017). The Chamber monitors standards for all facets in education and training in engineering (COET, 2017). It also pays attention to their members' career interests and validates the Continuing Professional Development (CPD) activities (as explained in 2.3.1.3) as per ECSA's requirements (COET, 2017).

2.4.7 South African National Committee on Large Dams

SANCOLD promotes good practice and technical excellence in all aspects of advancement in the dam sector (SANCOLD, 2017). These aspects include improving the planning, maintenance, design, management, construction, rehabilitation, operation and decommissioning of dams (SANCOLD, 2017). SANCOLD is also committed to developing South Africa's water resources ensuring safe, ecological, financial and socially sustainable standards (SANCOLD, 2017).

2.4.8 South African Society for Railway Engineering

The South African Society for Railway Engineering (SASRE) was formed in 1932 with the purpose to provide a platform for the exchange of knowledge relating to railway engineering. Their platform has now extended to broaden and improve the experience and effectiveness of their members (SASRE, 2016). They encompass railway engineering specialities and any associated technologies (SASRE, 2016).

2.5 Civil engineering work sectors

2.5.1 Overview of career trends

Civil engineers work in various sectors in the industry, ranging from national to local government, construction, consulting, project management and manufacturing companies (WorldWideLearn, 2017). Many engineers even venture into finance and banking industries with their degree (DeChesare, 2014).

2.5.2 Consulting Engineers of South Africa

Consulting Engineers South Africa (CESA) is an ECSA approved association that represents and promotes its members' interests and provides the utmost highest quality standard assurance for all their clients (Currie, 2017). Their membership includes in excess of 540 companies that employs over 24 300 people who are all members of CESA (Perrie, 2015). This voluntary association allows the public to find various disciplined engineering firms throughout the world and are found with their base in South Africa. They include a range of member firms spanning from small to medium sized, multinational and multidisciplinary firms providing fulfilment of all stages in a project cycle (CESA, 2017). They provide added creditability over and above ECSA individual membership. CESA promotes excellence within the consulting engineering sector and are continuously endeavouring to enhance and improve the industry (CESA, 2017).

2.5.3 Construction

A vast amount of civil engineers work for contracting companies, their involvement in a project begins at the outset in many cases (turn key projects or design and build) and they work closely with their clients and sometimes implement the project for them (Cattell et al., 2016). Adogbo et al. (2015) explains that other projects require the contractor only once all design and documentation is completed and finalised, and will then accordingly construct the project as per requirements.

In terms of affiliated organisations, the two main associations are SAFCEC (South African Forum of Civil Engineering Contractors) and CEA (SA) Constructional Engineering Association (South Africa). SAFCEC was established in 1939 and provides its members with a means to voice and advocate their best interests within

the contracting sector (Kriel, 2013). SAFCEC influences regulatory as well as policy changes that enables an environment that provides job creation and interests conforming to the Labour Relations Act (SAFCEC, 2017).

2.6 Professional Statistics (Quantification)

2.6.1 Professional Engineer

The Department of Higher Education and Training has enunciated in the 'List of Occupations in High Demand: 2015' that professional engineers are in high demand (DHET, 2015). The definition utilised by the Department that clarifies what an occupation in demand refers to is as adapted from DHET (2015):

It is an occupation that is experiencing shortages throughout the labour markets and also shows a considerable strong growth in employment. The list is still prevalent to this research since it will be reviewed in 2017, allowing a lifespan of 2 years per publication.

There are 3226 people to service for every professional engineer in South Africa, discipline specific statistics would accordingly be larger since there are more disciplines, but fewer professional engineers to be included in the spread (ESCA, 2015). This statistic brings light into precisely how scarce professional engineers are in South Africa and subsequent studies are to be conducted to address these indicators. Female engineers account for a mere 4.34 % of the total professionally registered engineers (ESCA, 2015). There will be 74 306 people to be serviced by one female engineer according to the 2015 statistics from the ECSA Annual Report (ESCA, 2015).

2.6.2 Professional Civil Engineer

By effectively utilising the scarce skills in a country, it places them on a conquering pathway leading to success (Petterson, 2016). With an unemployment rate of 27.7% in South Africa combined with the decline in employment growth within the Construction industry by 30 000 workers (based on quarter-to-quarter comparisons), the country requires an injection of practicable employment (StatsSA, 2017a). The

construction and civil engineering industry has the capability to create a large amount of jobs within short timeframes accompanied by providing training of skilled labour due to new legislation hence also providing sustainability (Ashpole, 2016).

For every professional civil engineer employed, it thus results in approximately 150 employment opportunities calculated from a project's inception, operation, completion and maintenance thereafter (Ashpole, 2016). The implications of generating more professional civil engineers provide positive corollaries into the sustainability, improvement and growth of a country (Ijagbemi et al., 2017).

2.7 Factors affecting conversion of candidates to professional engineers

2.7.1 Economy

With the recent stunted economic growth, and recession that South Africa is experiencing, the country requires a vast amount of strategic planning to revive the economy and stimulate exponential growth (Maasdorp, 2016). Engineers are educated to fulfil the planning and designing of this vital aspect in the recovery and sustainability of the economy (Wan Alwi et al., 2014). However with the poor economy and roll-out of government funded projects, many qualified engineers are on retrenchment lists and are on the brink of changing career paths (CESA, 2016).

2.7.2 Standard of education

Findings by Ackah-Baidoo (2016) indicate that the impacts of the sub-standard levels of education in South Africa cause severe economic implications for the country. Correspondingly, Spaul (2013) highlights that this is worsened by the deterioration of the economic prospects for the youth of the nation. In South Africa, only 1 378 433 people above the age of 20 has attained a bachelor's degree or higher which amounts to 2.48% of the total population (StatsSA, 2016).

South Africa featured 19th in global ranking from the latest Global Gender Gap Report, they have managed to close 78% of the gender gap, however have dropped to 64th for educational attainment from 42nd in 2016 out of 144 countries (Hausmann et al., 2017). The ratio for educational attainment comprises of statistics for literacy, net primary and secondary enrolment, as well as the gross enrolment into tertiary academia (Hausmann et al., 2017). Access to education is not the only solution to

the problem of under representation of females but rather there is changes in the multidimensional policymaking sectors that requires additional attention (Greve, 2013).

2.7.3 Unemployment and Emigration

Although South Africa's engineering abilities and skills are sought after and well recognised throughout the world, the same sentiment cannot be said in South Africa itself (PPS, 2012). Pillay (2013) believes that South Africa has excellent engineers. These professional engineers are found both in the local context as well as those who have immigrated due to promulgated legislation created by the government which provides the ideology that the socio-political inclination is against professional engineers, especially those who are white (Pillay, 2013)

This is further reiterated by Bowen et al. (2013, p.631), who found evidence which confirmed that white engineers felt more discriminated against with regard to job security than their Black counterparts. It is reverse apartheid due to affirmative action and BEE (Black Economic Empowerment) regulations and policies (Lindsay, 2016). Despite the skills shortage of engineers, the South African labour market is still characterised by the high increase in unemployment rate (DHET, 2015). Castillo et al. (2014) confirms that with the current trends of the market, retention of professional engineers is imperative irrespective of the race group or gender. Discrimination in the form of regulations or policies decreases feelings of job security and future growth (Adams, 2015). The migration of women from engineering to other lines of work constitutes a significant loss to the engineering profession of both talent and the different perspective that women in general bring to the profession and to the public in providing engineering services (Musselman, 2013)

2.7.4 Imbalance

Historically, engineering fields have had particularly low concentrations of women and members of many racial and ethnic minority groups, both relative to the concentrations of these groups in other occupational or degree areas and relative to their representation in the general population (NSF, 2014a). As researchers and policymakers increasingly emphasize the need for expanding the number of females in engineering, there are many changes within the attitude in the workforce that

needs to occur (Giudice, 2014). There is a lack of motivation and role models to provide a reason for females to persist in the engineering sector (Alpay et al., 2010). Many females rather focus on a career that allows for a family life, as opposed to staying in engineering (Martin & Barnard, 2013). Studies by Colvin et al. (2013) and Martin et al. (2015) show that the United Kingdom and Europe's current Science, Engineering and Technology (SET) statistics indicates a significant variance in the gender imbalance present with females in the SET fields. Post university, twenty (20) per cent of females are employed in the SET related occupations (Martin et al., 2015).

Colvin et al. (2013, p.36) states that data indicates an underrepresentation of women in the mathematics, science, engineering and technology fields, with engineering amounting to the highest underrepresentation. Research by Xu (2017) supplement studies by Colvin et al. (2013) and have observed that women tend towards careers in health sciences or disciplines that they perceive they can help others in and STEM graduates remains low. Many students are not aware of what engineering inculcates (Meyer & Marx, 2014).

Females are more harassed in addition to being discriminated against in the South African construction industry (Bowen et al., 2013). Research done by Cattell et al. (2016) provided evidence that due to higher stress levels in this industry there are higher cases of females leaving the profession. In addition, studies done by Ceci et al. (2014) indicate that women leave engineering because they are dissatisfied with their pay and lack of promotion opportunities.

It was found from a study conducted by Organisation for Women in Science for the Developing World and the Women in Global Science & Technology, that by undertaking gender benchmarking in leading economies of the world, female representation was on the decline and levels were alarmingly low in the science, innovation and technology sectors (Greve, 2013). It becomes apparent to deduct that most countries are experiencing the same prevailing paradigm relating to the lack of female representation in the engineering sector.

The current trends from Statistic SA indicates that the number of females employed in the formal sector in South Africa has been stagnant with minimal increases since 2008 as seen in the figure adapted from statistics compiled from StatsSA (2017b). This further solidifies that if females are underrepresented collectively in all facets of the employment sector, it is without a doubt that engineering will have a deficiency as well since it amounts to a small fraction of this statistic but is still unknown.

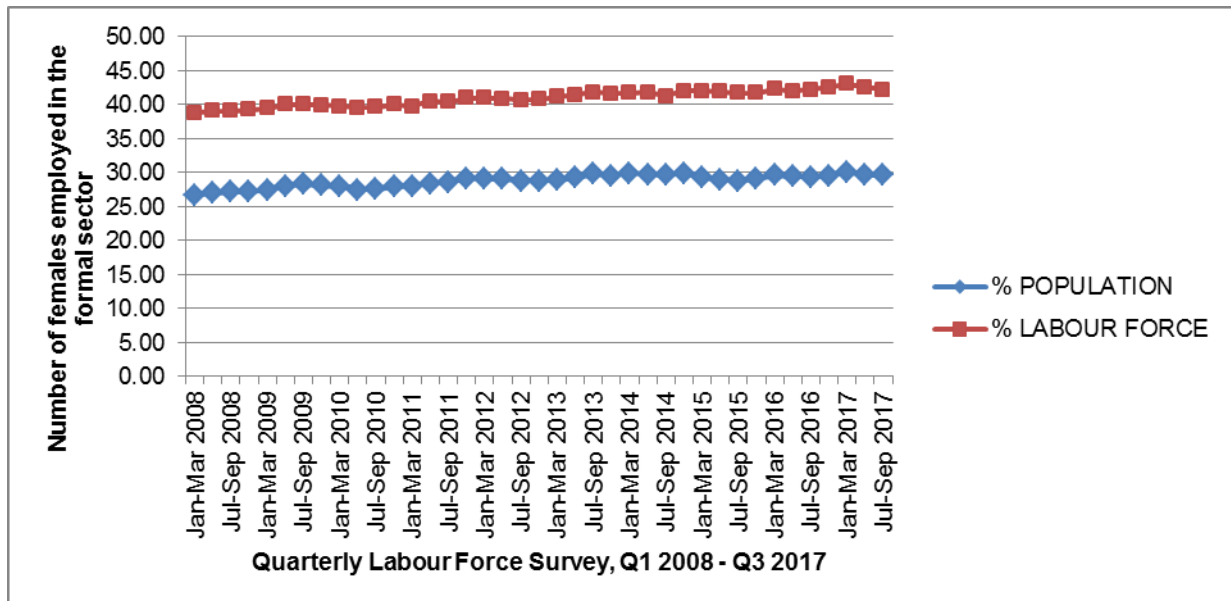


Figure 2.1: Percentage of females employed in the formal sector (non-agricultural) As adapted from Quarterly Labour Force Survey, Q1 2008 - Q3 2017 (STATSSA, 2017)

2.8 International professional practices

2.8.1 Background information

In view of the fact that ECSA has an international agreement with the Washington Accord, which is an alliance that governs reciprocated recognition and competence of engineering qualifications as well as professional competence, it is thus pertinent that these signatories were investigated. The list includes the Australia (Engineers Australia), Japan (JABEE), United Kingdom (ECuk), Chinese Taipei (IEET), Singapore (IES), Canada (CCPE), New Zealand (IPENZ), Hong Kong, China (HKIE), Korea (ABEEK), United States of America (ABET) and Ireland (Engineers Ireland) (ECSA, 2017c).

2.8.2 Professional Engineers statistics

For every licenced engineer in USA, he/she would have to service 367 people (NCEES, 2017). However this number is inflated due to a few people that are licenced in different states and are accounted for in each of those states as well. Females amount to 12,7 % of the engineering sector (NSF, 2014b). There is still a large underrepresentation of females in the United States engineering sector (Robinson, 2012).

Engineering works is determined by financial provisions and not just the number of people involved (Neidecker, 2010). A better understanding of this is found by the GDP to engineer metric as shown in Table 2.9. A good comparison can be made with the United Kingdom which has a similar population (10 million more) and with a higher GDP (788% more), that still produced GDP to engineer ratios of US\$11.32 as opposed to South Africa's ratio of US\$17.84. Accordingly, the deficiency of engineers as established by the metric of GDP (US\$ million) to engineer, suggests a colossal lower shortfall, which supports other indicators for example those yielded by ECSA and recent anecdotal observations such as CESA. Another benchmark is to compare South Africa with the average of the English speaking countries that are signatories of the Washington Accord, i.e. UK, Canada, USA, Australia, Ireland and New Zealand (ECSA, 2017c).

These countries have an average GDP (US\$ million) to engineer of US\$ 11.40 and with an average population per engineer ratio totalling 259:1. South Africa has a GDP (US\$ million) to engineer of US\$17.84 which is 57% higher than their average statistics and the population per engineer ratio of 3383:1, which is 1206% more. Due to the increase in South Africa's population yearly, a subsequent increase in engineers is necessary to provide for the unavoidable increase in level of service, this would require an increase in GDP to fulfil the productivity of this impact due to the provision of infrastructure and hence funding or budgets required to provide for this expansion (Watermeyer, 2012). This highlights the fundamental need for finance in order to deliver and maintain infrastructure (Ehlers, 2014). South Africa has a GDP per capita income of US\$5 273 as opposed to average comparative figure calculated for UK, Canada, USA, Australia, Ireland and New Zealand at US\$48 414. There is distinct indication that South Africa will be compelled to increase the number of

registered engineers and GDP to sustain the current population as well as future increases in population size.

Table 2.9: Population and GDP per engineer in different countries as at 2015/2016
As adapted from various sources (BEM, 2016, CONFEA, 2016, ECSA, 2016, ENGC, 2016, EngineersAustralia, 2016, FEANI, 2016, HKIE, 2016, IES, 2016, IPEJ, 2016, KPEA, 2016, NCEES, 2017, VDI, 2016)

Country	GDP (Million of \$)	Population	Number of registered engineers	Population per registered engineer	GDP rank	GDP per capita (Atlas rank \$)	GDP per capita (US\$)	GDP per engineer (US\$ million)
Western Europe								
Denmark*	306 142.94	5 731 118	83 000	69	34	13	53 417.66	3.69
Finland*	236 785.05	5 495 096	78 589	70	43	23	43 090.25	3.01
France*	2 465 453.98	66 896 109	220 000	304	6	33	36 854.97	11.21
Germany*	3 466 756.88	82 667 685	154 251	536	4	25	41 936.06	22.47
Greece*	194 558.65	10 746 740	85 000	126	47	59	18 103.97	2.29
Iceland	20 047.41	334 252	2 100	159	105	12	59 976.94	9.55
Ireland*	294 053.60	4 773 095	17 801	268	39	18	61 606.48	16.52
Norway*	370 556.67	5 232 929	62 000	84	29	6	70 812.48	5.98
Sweden*	510 999.80	9 903 122	130 000	76	22	16	51 599.87	3.93
UK*	2 618 885.69	65 637 239	231 439	284	5	27	39 899.39	11.32
Eastern Europe								
Hungary	124 342.94	9 817 958	7 200	1 364	56	76	12 664.85	17.27
Romania	186 690.60	19 705 301	12 500	1 576	50	88	9 474.13	14.94
North America								
Canada*	1 529 760.49	36 286 425	290 000	125	10	24	42 157.93	5.28
USA*	18 569 100.00	323 127 513	881 438	367	1	14	57 466.79	21.07
South America								
Brazil	1 796 186.59	207 652 865	860 252	241	9	90	8 649.95	2.09
Australia								
Australia*	1 204 616.44	24 127 159	101 144	239	14	17	49 927.82	11.91
Asia								
China	11 199 145.16	1 378 665 000	10 000 000	138	2	93	8 123.18	1.12
Hong Kong	320 912.24	7 346 700	15 314	480	32	26	43 681.14	20.96
India	2 263 522.52	1 324 171 354	6 500 000	204	7	170	1 709.39	0.35
Japan*	4 939 383.91	126 994 511	103 534	1 227	3	34	38 894.47	47.71
Korea Rep	1 411 245.59	51 245 707	46 799	1 095	11	45	27 538.81	30.16
Malaysia	296 359.12	31 187 265	11 456	2 722	37	85	9 502.57	25.87
Singapore	296 965.71	5 607 283	4 853	1 155	36	19	52 960.71	61.19
Africa								
South Africa	294 840.65	55 908 865	16 526	3 383	38	113	5 273.59	17.84

* First World Countries

2.8.3 Statistics of females in engineering and general observations

Professional role confidence is a concept by Cech et al. (2011) that relates the ability to successfully perform a professional role amalgamated with finding enjoyment as well as fulfilment in this professional sector. It looks at the difference in gender persistence within the engineering sector with regard to professional role confidence and the results indicated that men developed this persistence more successfully than females (Buse et al., 2013).

Studies completed by Buse et al. (2013, p.151) indicate that women opt out/ leave the engineering profession due to difficulties experienced in relation to the male dominated facets that drive them to. It shows that the women who continue to persevere and overcome the difficulties as mentioned, enable them to discover fulfilling as well as rewarding experiences in the profession of engineering.

A research report by Fouad and Singh (2011) provides data from an extensive survey of 3,745 women educated in engineering. The surveys were sent to female alumnae of engineering programs from a diverse set of 30 universities throughout the U.S. The results show that women leave engineering more readily than men. Supporting this observation, studies by Glass et al. (2013) enunciates that females in the STEM industry have a tendency to leave their occupation and relatively early in their careers when compared to other professions. Between one-quarter and one-third of women who leave engineering do so to provide full-time family care, however the majority of women who leave the profession usually transfer predominantly into executive and management positions (Musselman, 2013).

Co-operatives and internships were found to play important key roles in female undergraduate student's programmes and decision-making on whether to continue in the civil engineering field in Washington, USA (Raelin et al., 2014). It influences their perceptions of engineering as a career choice and their tertiary academic outcomes (Lichtenstein et al., 2014). The internships and co-operatives boost their confidence and initiates motivations to persist in the engineering sector (Habib, 2015). It allows them to develop from work stimulated scenarios and hence develop skills that would assist them in the professional sphere, i.e. collaboration as well as communication skills (Musselman, 2013). It also provides them with possible employment

opportunities by exposing them to network opportunities or connections (Samuelson & Litzler, 2013).

In order to retain females in the engineering sector, managers and organisations need to recognise the vital importance of a female's family life and the skills required to continue to persist in this male-dominated profession (Groysberg & Abrahams, 2014). It was found from studies by Lichtenstein et al. (2014) that organisations who were supportive of family circumstances and provided opportunities to focus and develop on professional role confidence were more inclined to retain females in their work force. Women ultimately changed jobs to attain a balance in their work and family life (Cahusac & Kanji, 2014). This proves the requirement of more supportive employees/jobs to manage the high demands of the profession (Buse et al., 2013). Sex segregation within labour markets throughout the world is still not completely understood and many social scientists are continually investigating the causes and correlations despite it being ubiquitous (Lippa et al., 2014). Ample studies were found in the international context however statistics and qualitative studies locally were absent for the civil engineering industry.

2.9 Conclusion

Engineers are a crucial component that affects the South African prosperity, sustainability and economy. It is imperative that South Africa takes cognisance of these results to ensure that we preserve their key proficiencies. It is vital that South Africa looks into the issue of their skills shortages in addition to whether there is enough being done in order to promote the engineering profession among the South African youth. Civil engineers were established to be the foundation of the engineering profession and the decision to elaborate and study this sector was appropriately justified as discovered in the literature review. ECSA plays an important role in the engineering industry and are at the forefront of changes in policy regarding registration and any associated professional requirements and standards. ECSA however does not provide any timeframes relating to the conversion from graduates to professional status. This would aid in estimating if the number of graduates being produced are sufficient to provide for the number of professional engineers required over the years. The demand for professional engineers was deduced from comparison to international standards and statistics.

This showcased the lack of professional engineers in South Africa and the need to address this deficiency. It became apparent that the admission and retention of females in both engineering institutes and in the work place is undesirably low and depends on many variable factors. One sole factor could not be labelled as the main aspect that must be implemented to obtain higher female graduate and professional statistics. The research into gender differentiation and gaps in knowledge were revealed showcasing the lack of information in South Africa regarding the graduate and professional statistics and studies.

It is in the authors opinion that the goal of this chapter was successfully achieved and that the knowledge that was acquired from this chapter can be effectively applied to the remainder of the study. The literature review provided a means to critically analyse and discuss existing literature pertaining to the motivation for the study. The literature review assisted in the structuring of the methodological approach and aided in focusing the study to produce the desired outcome.

CHAPTER 3 : RESEARCH METHODOLOGY

3.1 Introduction

This chapter outlines the methodological approach and procedure undertaken for this research. The methodological approach included identifying alternative methods, which were analysed and explained thereby leading to the decision of the final methodological approach. The decision of this final approach was elucidated and justified. Explanations regarding the type of data collected, the methods of collection, data analysis and motivations behind critical choices in the methodology are provided.

3.2. Aim of the study

The aim of the study was to investigate the current professional engineers' statistics as well as synthesise and critically interrogate the 2001-2014 graduate and professional civil engineer statistics. Cross examination into well performing universities were established via comparative studies concluded by the research undertaken for timeframes needed to convert to professional status. Possible trends for future targets and inclinations were determined.

3.3 Research Philosophy

An imperative research consideration when deciding in the philosophical framing is the epistemology (Mora, 2012). Epistemologically, an extreme positivist's position focuses on uncovering observable measurable regularities, facts and only on phenomena that can be observed and measured to produce credible and meaningful findings/data (Saunders et al., 2015). In conducting this research, the positivist view of accuracy as well as replicable documentation were focused on, leading towards valid generalisation (Mora, 2012). Positivist worldviews utilise the traditional research form to which these assumptions prove more reliable for quantitative studies as opposed to qualitative studies (Creswell, 2014). The emphasis of positivism lies solely in the scientific empiricist technique designed to produce pure data or facts that is uninfluenced by human biasness or interpretation (Saunders et al., 2015). Systematic research is key in business and management studies and following a positivists worldview enables that to be fulfilled (Saunders et al., 2015).

3.4. Approach to theory development

There are three approaches predominately used in research theory development, deductive, inductive and abductive (Saunders et al., 2015). Since this study began with theory developed in the form of a literature review denoting the lack of professionally registered engineers, which resulted in the research strategy which endeavoured to test the theory and decipher current statistics and correlating demand requirements.

The logic behind deductive research indicates that when the set of premises are shown to be true, the conclusion must correspondingly be true (Saunders et al., 2015). The generalisability of the research encompassed generalising from all engineering disciplines to a specific discipline being civil engineering and further into gender specific comparisons. The use of data collection was undertaken to evaluate the hypotheses as stated related to the existing literature reviewed. This is in line with deductive reasoning as opposed to data collection being used for exploration of a phenomenon and hence the identification of central themes and/or patterns to create conceptual frameworks as found in inductive research development (Saunders et al., 2015). Abductive reasoning takes it another step further by testing those frameworks through consequent data collection (Saunders et al., 2015).

Another factor that infers the deductive approach for this study is the theory verification or contradiction with regards to gender specific employment targets by utilising findings from the research. In addition to proving that the literature showcasing low levels of professional engineers with emphasis on civil engineers are valid. Comparing this with theory generation or incorporation of existing theory as found in induction and abduction approaches would not fit this research design.

3.5 Methodological choice

Methodological choice is concerned with how or the method that the researcher will use to generalise the data, either qualitatively or quantitatively (Ahmed et al., 2016). There are three approaches namely mixed method qualitative and quantitative research studies (Creswell, 2014). Several descriptions and definitions exist for a mixed method research design (Bryman & Bell, 2015). Cameron (2010) defines it as an integration of qualitative and quantitative methods.

Bryman and Bell (2015:45) state that “theory can be depicted as something that precedes research (as in quantitative research) or as something that emerges out of it (as in qualitative research).” This study follows theory that precedes the research resulting in a quantitative research design. This is further characterised as a mono method quantitative study since a single data collection method is utilised with a corresponding quantitatively analytical procedure (Saunders et al., 2015).

The data in this study was found in numerical form leading the study to be analysed by using quantitative techniques (Azorín & Cameron, 2010)

3.6 Research Strategy

Ang (2014) clarifies that when conducting quantitative studies, the most common strategies include the collection of archival data, surveys and to a smaller extent experiments.

Archival research is based on utilising documentary records or sources (Thomas, 2004). Archival research is used for analysing publications, company records, documents or similar data for evidence (Maylor et al., 2017). This form of data does tend to provide otherwise forgotten or lost acumens into managements decisions uncovering rich detailed information which has never become public or was never analysed (Maylor et al., 2017).

O’Leary (2013) suggests that since the documents used as sources were already produced for a different purpose other than specifically being created for an archival research project, the strategy is seen as a secondary analysis although no data existed before the analysis. In this research study, a structured content analysis was the technique applied in order to use the archival data as a means to find and generate meaningful statistics in the datasets. Microsoft Excel was the computer programme that assisted in this endeavour to a certain extent.

Case studies was a possible strategy that was considered for this study however Maylor et al. (2017) states that case study strategies utilise both quantitative and qualitative methods for gathering data. If both methods prove the same findings then

greater confidence can be found in the chosen strategy. This proved that case studies could not be utilised to fulfil the aims and objectives of this research study.

3.7 Time Horizon

An imperative factor to be included in research design is the time frames. Saunders et al. (2015) states that there are two time horizons that can be utilised namely cross-sectional and longitudinal horizons. Sekaran & Bougie (2016) state that if data is collected just once spanning a period of days, weeks and/or months in an attempt to answer the research question then it is known as a “one-shot” or cross-sectional study. In addition, Saunders et al. (2015) refers cross-sectional to a “snapshot” time horizon and longitudinal to a “diary” perspective. The nature of cross-sectional time horizons relies on data collection being time-bound (Rose et al., 2014). Thus it fits this research design since statistics are found over a specific period (2001-2014) and does not require a chronological sequence of how things have changed over time as is found in longitudinal studies.

3.8 Data Collection

Data collection concerning the literature review involved the use of books, journals, past dissertations, scientific articles, websites from the worldwide web, various articles and conferences. This provided a basis for relevant comparisons. Primary data is data that is collected for the first time by a researcher whilst secondary data is already collected and/or produced by other sources (Maylor et al., 2017).

The data sources for the study were from ECSA’s database and annual reports which are available online as well as data from four of the six ECSA accredited universities (UKZN, UP, UCT, WITS). Graduate lists were collected from the universities spanning the 14 year time frames and the surnames of each graduate were inputted into ECSA’s database. Every registered engineer can be identified by their surname on ECSA’s website under the section titled: “Who is Registered.” The registration details include their name, surname, current category (candidate, professional or certified), discipline, registration number, registration status (active, cancelled or deregistered) and the date of registration. According to U.S. News and their Best Global Universities per Subject Rankings, South Africa has 4 universities that featured in their top 500 for Engineering. The participating universities in this

ranking were from the United States of America and sixty other countries amounting to the world's top 1250 Best Global Universities list (U.S.News, 2016). The subject-specific ranks are purely based on the universities' academic research performance for those specific subjects (engineering) based on thirteen indicators (U.S.News, 2016).

According to U.S.News (2016), these top well-regarded South African universities have displayed strength in the production of research relating to various engineering topics and have been used in this study. They are in order of subject rank (U.S.News, 2016):

Rank 357 – University of Pretoria

Rank 397– University of Witwatersrand

Rank 422– University of KwaZulu-Natal

Rank 483 - University of Cape Town

These specific universities were included in this study making their validity indubitable. Various forecasting percentages and ratios were deduced from the results providing a better insight into the engineering fraternity and future trends.

An overview for the methodological approach that was adopted in this study included the following:

- Collation of data from ECSA's annual reports was gathered regarding the number of professional engineers who have transferred from candidate status.
- Comparative analysis of gender statistics was compiled to highlight any differences.
- Graduated civil engineers' statistics was captured from records provided by the ECSA accredited universities as stated. Names of graduated civil engineers were then checked on ECSA's database to confirm when registered as professional engineer.
- Once again a comparative analysis of gender statistics was compiled. Ratios were formulated showing the differences in statistics and number of years taken to achieve professional statics.

- Details into the demand for engineers were analysed and compared to current supply statistics. Provision for deterministic future supply was compiled from the preceding developed statistics and ratios.

3.9 Data Review and analysis

Excel with the graph function was used to illustrate the comparative study between the areas. Comparison of the demand and supply required South Africa was also done by the following methods:

- Comparisons in terms of population to engineer ratios. This led to a critical analysis of the possible improvements that could be implemented to reach higher levels of statistics.
- Tables showing the difference among each university and gender in the graduate and professional categories.
- Tables showing the time frames taken to achieve professional status during the allocated time frames 2001-2014 together with corresponding universities and gender differentiation.
- Averages and standard deviations to account for any discrepancies during synthesising of the results.
- Graphs and ratios for forecasting of trends developed from the results for future estimations in terms of graduates and professional civil engineers.

3.10 Validity, generalisability and reliability

Validity refers to whether the findings from the research are actually what they claim to relate to (Rose et al., 2014). The study has content, construct and convergent validity. The external validity of the study applies to both people and time other than those contained in which the study was conducted. This is found by the fact that the engineers under investigation during 2001-2014 will undoubtedly provide trends and drivers that affect policy maker's decision going forward regarding realistic statistics and employment targets for the future. This is also known as generalisability (Rose et al., 2014). In addition, since the research has a positivist worldview undertone, by providing generalised results has solidified the research design.

Reliability is concerned with measuring the stability and consistency of results ensuring repeatability (Wilson, 2014). Since this study is statistical and highly dependent on mathematical equations as a basis for extracting data, the repeatability, reliability and consistency of the study is unwavering.

3.12 Research Limitations

Results and analysis in this research project depended to some extent, on existing data. Acceptance of this data, implies that it must however, be assumed that the information obtained is correct and reliable. The data relating to the actual number of professionally registered engineers extracted upon inception will be used in comparisons and will be assumed to be correct. Unavailability of precise data posed a great hindrance in exact comparisons. Provision of archival data from four (4) out of the six (6) ECSA accredited universities deemed to be a limitation however was overcome by utilising averages and subsequent standard deviations. Due to time constraints, the study could not have been as in-depth as needed and only civil engineers were investigated. Since there was no sample or interviews, the study was limited. Lack of exiting data on statistics for civil engineers and insight into reasons for gender inequality within South Africa proved to limit quantitative/qualitative theory for the literature review but further highlighted the need for this study.

3.13 Conclusion

This choice of methodology which included the different approaches, analyses, and comparisons drawn, enabled this dissertation to accomplish its aims and objectives. Wherever limitations and uncertainties were discovered, they were duly highlighted and/or explained. By following the methodology as described, the relevant studies were undertaken as presented under the relevant sections. The author believes that the methodology used was adequate to fulfil the aims and objectives for this research study.

CHAPTER 4 : RESULTS

4.1 Introduction

There were two major comparisons linking to the study, firstly ECSA's annual reports provided vital information regarding the current statistics of all engineers in the country. Deductions from Chapter 2 and 3 resulted in the need for a continuation of the study into the specific field of civil engineering to highlight the differentiated statistics of graduates transferring to professional status and the time frames that is required for this transition. The results were gathered from the specific universities as stated in par 3.8 Data Collection. Various forecasting percentages and ratios were deduced from the results providing a better insight into the engineering fraternity and future trends. The time frames for conversion into professional status were determined from the data analysis provided by checking the graduate status on ECSA's database. In addition comparisons of gender, race and university averages were compiled with future extrapolations.

4.2 ECSA Statistics

ECSA provides a holistic view of the current statistics that our country produces regarding all disciplines in engineers. The annual reports provide legislatively-prescribed registration categories for engineering professionals (ESCA, 2015). This follows the Engineering Professionals Act No. 46 of 2000 necessary terms (EPA46, 2000). The categories and related statistics for total registrations (professional), new registrations, transfers from candidates, cancellations and deregistration's were taken from the various ECSA annual reports. There was a lack of informative statistics prior to 2008. The totals for each category or status of progress of registrations are provided in Table 4.1. The yearly change in total professional registration statistics is noted in Figure 4.1.

Table 4.1: Yearly totals for engineers in different categories

As adapted from various ECSA Annual reports (ECSA, 2006, ECSA, 2007, ECSA, 2012, ECSA, 2013, ECSA, 2014, ECSA, 2015, ESCA, 2009, ESCA, 2010, ESCA, 2011, ESCA, 2017)

YEAR	Total registrations	New registrations	Transfers from Candidates	Cancellations	Deregistrations
2002/2003	14687				

(Continued)

YEAR	Total registrations	New registrations	Transfers from Candidates	Cancellations	Deregistrations
2003/2004	14728				
2004/2005	14754				
2005/2006	14745				
2006/2007	14503				
2008/2009	14476	543	196	223	625
2009/2010	14639	412	204	281	88
2010/2011	14696	470	234	276	79
2011/2012	15168	546	328	73	84
2012/2013	15597	646	409	142	63
2013/2014	16205	800	502	103	59
2014/2015	16423	556	361	180	58
2015/2016	16526	504	352	13	81
2016/2017	16733	868	613	8	76
$\Delta(2002-2017)$	2046				

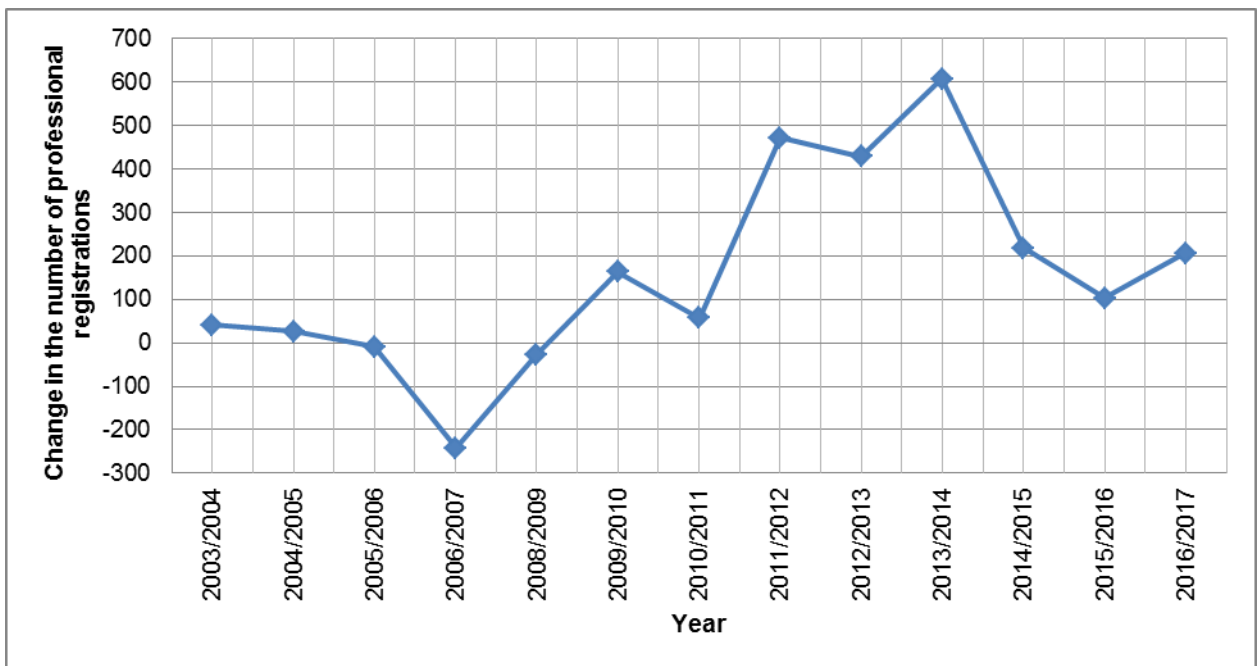


Figure 4.1: Total number of new registered professional engineers registered with ECSA per year

A more precise and comprehensive comparison will require the transfers statistics as opposed to the complete total registrations since that can include immigrant registrations and conversions from other categories (i.e. A technologist who studied further at a university, converted his/her diploma into a degree and applied for

acceptance into the Professional Engineer category). It is thus imperative that the analysis be compared to transfers from candidate category to professional category per gender as depicted in Figure 4.2.

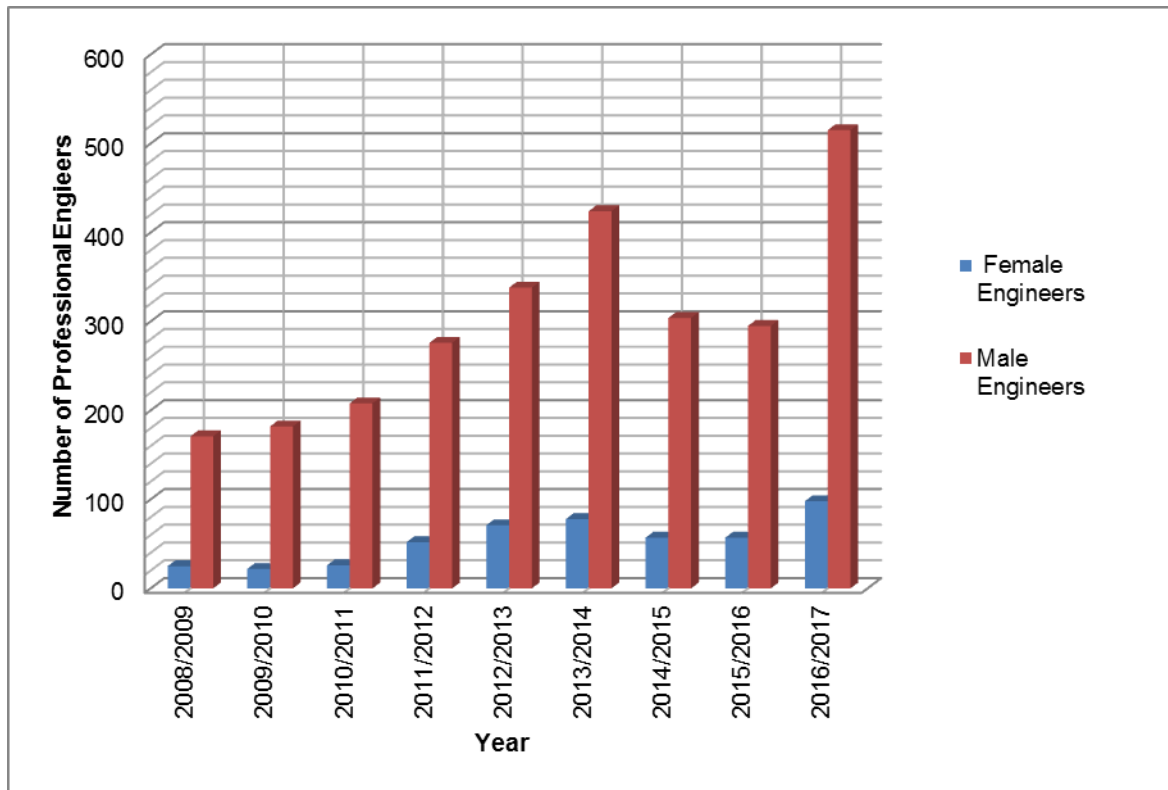


Figure 4.2: Total Professional engineer gender comparison transfers

The total number of professional engineers with gender and race differentials can be ascertained in Table 4.2 for the current year 2016/2017 as customised from ESCA (2017).

Table 4.2: Showing the professional engineer statistics from ECSA annual report 2016/2017

2016/2017 Professional Engineer Statistics						
		Total registrations	New registrations	Transfers from Candidates	Cancellations	Deregistrations
Cululative Totals		16733	868	613	554	76
Gender	Male	15868	744	515	526	72
	Female	865	124	98	28	4
Race	Black	1857	266	183	84	0
	White	13582	462	320	426	75
	Indian	1105	119	91	36	1
	Coloured	189	21	19	8	0

The gender and race comparisons are further highlighted in the figures below in percentages as adapted from ESCA (2017).

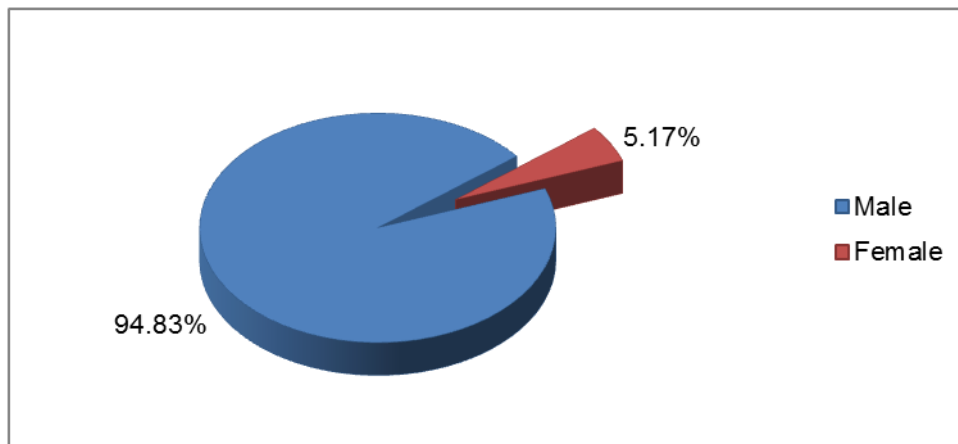


Figure 4.3: Total professional engineers (%) per gender as at 2016/2017 statistics

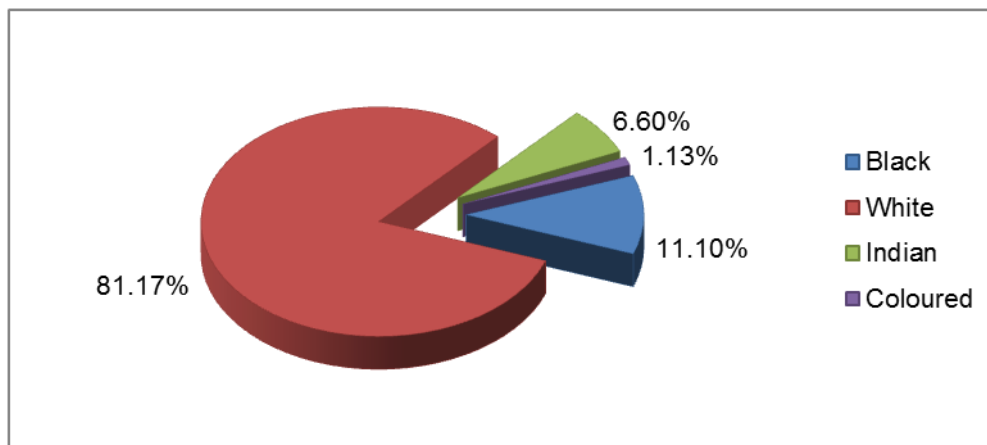


Figure 4.4: Total professional engineers (%) per demographic as at 2016/2017 statistics

4.3 Civil Engineering Statistics

Graduate information was gained from four out of the six ECSA accredited universities in South Africa, namely University of Cape Town(UCT), University of KwaZulu-Natal (UKZN), University of Pretoria (UP) and the University of Witwatersrand (WITS). The names of graduates were then checked on ECSA's database to ascertain where they are in their professional status. The different varying professional categories on ECSA's website were labelled as registered, candidate and cancelled. Those names that were not found on ECSA's database were labelled as "not on ECSA's database". The summary is presented in Table 4.3.

Table 4.3: Summary of graduate statistics and ECSA Professional status inclusive of gender divisions

Year	University	CUMULATIIVE					FEMALE STATISTICS					MALE STATISTICS				
		Graduates	Registered	Candidate	Not on ECSA's database	Cancelled	Female Graduates	Registered	Candidate	Not on ECSA's database	Cancelled	Male Graduates	Registered	Candidate	Not on ECSA's database	Cancelled
2001	UKZN	37	18	6	8	5	4	0	2	1	1	33	18	4	7	4
	UP	2	1	1	0	0	0	0	0	0	0	2	1	1	0	0
	UCT	51	14	6	24	7	14	1	1	8	4	37	13	5	16	3
	WITS															
2002	UKZN	26	13	2	6	5	7	3	0	2	2	19	10	2	4	3
	UP	27	14	3	7	3	7	2	1	4	0	20	12	2	3	3
	UCT	33	9	3	17	4	9	2	0	7	0	24	7	3	10	4
	WITS															
2003	UKZN	24	10	6	8	0	2	0	1	1	0	22	10	5	7	0
	UP	15	8	0	4	3	1	0	0	1	0	14	8	0	3	3
	UCT	34	8	4	15	7	10	1	2	5	2	24	7	2	10	5
	WITS															
2004	UKZN	29	16	3	5	5	4	3	0	1	0	25	13	3	4	5
	UP															
	UCT	27	14	2	8	3	6	2	0	3	1	21	12	2	5	2
	WITS															
2005	UKZN	29	8	6	10	5	9	1	1	4	3	20	7	5	6	2
	UP	29	13	3	9	4	3	2	0	1	0	26	11	3	8	4
	UCT	25	9	2	8	6	8	3	1	1	3	17	6	1	7	3
	WITS															
2006	UKZN															
	UP	24	13	5	5	1	4	2	0	1	1	20	11	5	4	0
	UCT	34	12	4	13	5	12	4	2	4	2	22	8	2	9	3
	WITS															
2007	UKZN	31	9	12	7	3	13	3	5	4	1	18	6	7	3	2
	UP	36	19	9	4	4	9	1	3	3	2	27	18	6	1	2
	UCT	45	14	8	18	5	9	2	0	5	2	36	12	8	13	3
	WITS	32	12	10	5	5	5	0	3	0	2	27	12	7	5	3
2008	UKZN	34	14	14	5	1	0	0	0	0	0	34	14	14	5	1
	UP	32	15	5	8	4	6	1	0	3	2	26	14	5	5	2

(Continued)

Year	University	CUMULATIVE					FEMALE STATISTICS					MALE STATISTICS				
		Graduates	Registered	Candidate	Not on ECESA's database	Cancelled	Female Graduates	Registered	Candidate	Not on ECESA's database	Cancelled	Male Graduates	Registered	Candidate	Not on ECESA's database	Cancelled
08	UCT	53	17	15	12	9	14	4	5	2	3	39	13	10	10	6
	WITS	21	6	7	2	6	5	1	2	1	1	16	5	5	1	5
2009	UKZN	48	14	25	7	2	19	5	10	3	1	29	9	15	4	1
	UP	54	22	12	15	5	16	1	5	9	1	38	21	7	6	4
	UCT	57	13	22	17	5	16	1	5	9	1	41	12	17	8	4
	WITS	32	10	15	5	2	10	1	6	3	0	22	9	9	2	2
2010	UKZN	56	4	40	8	4	13	3	4	4	2	43	1	36	4	2
	UP	53	17	17	14	5	13	3	4	4	2	40	14	13	10	3
	UCT	78	10	41	21	6	23	1	11	7	4	55	9	30	14	2
	WITS	40	6	25	5	4	11	0	10	1	0	29	6	15	4	4
2011	UKZN	76	4	55	12	5	17	0	13	3	1	59	4	42	9	4
	UP	91	19	46	20	6	24	2	10	11	1	67	17	36	9	5
	UCT	70	3	40	19	8	18	0	8	7	3	52	3	32	12	5
	WITS	53	3	33	10	7	17	0	12	2	3	36	3	21	8	4
2012	UKZN	54	0	42	12	0	19	0	14	5	0	35	0	28	7	0
	UP	100	12	61	22	5	20	1	12	7	0	80	11	49	15	5
	UCT	86	2	46	34	4	26	0	12	12	2	60	2	34	22	2
	WITS	55	2	42	6	5	12	0	11	1	0	43	2	31	5	5
2013	UKZN	51	0	44	7	0	7	0	7	0	0	44	0	37	7	0
	UP	154	0	118	30	6	44	0	29	12	3	110	0	89	18	3
	UCT	84	0	37	46	1	26	0	11	14	1	58	0	26	32	0
	WITS	58	0	42	13	3	21	0	16	5	0	37	0	26	8	3
2014	UKZN	77	0	66	11	0	24	0	22	2	0	53	0	44	9	0
	UP	141	0	97	34	10	38	0	26	9	3	103	0	71	25	7
	UCT	73	0	36	37	0	18	0	11	7	0	55	0	25	30	0
	WITS	82	0	63	19	0	25	0	17	8	0	57	0	46	11	0

4.3.1 Graduate civil engineers

The raw data was then condensed into cumulative totals and hence averages were calculated due to the varying provision of archival data of the graduates from each university. The University of Cape Town provided the most data backdating 14 years beginning in 2001 until 2014. The University of Johannesburg only provided graduate numbers spanning 2002-2014. The gender and graduate comparisons were also included. These summaries are found in Table 4.4 and Figure 4.5.

Table 4.4: Analysis of total graduate statistics and ECSA Professional status in each university

		Graduates	Registered	Candidate	Not on ECSA's database	Cancelled	Archival data (years)
UKZN	Total	572	110	321	106	35	13
	Average	44	8	25	8	3	
UP	Total	758	153	377	172	56	12
	Average	63	13	31	14	5	
UCT	Total	750	125	266	289	70	14
	Average	54	9	19	21	5	
WITS	Total	373	39	237	65	32	8
	Average	46	5	30	8	4	
UJ	Total	413					13
	Average	32					
Cumulative Totals		2453*	427*	1201*	632*	193*	*Excluding UJ
Female Totals		634	53	321	202	58	Female Statistics
Total Statistics/ Female Statistics (%)		25.85	12.41	26.73	31.96	30.05	
Total Graduate/ Female statistics (%)			2.16	13.09	8.23	2.36	
Female total grads/ Female statistics (%)			8.36	50.63	31.86	9.15	
Male Totals		1819	374	880	430	135	Male Statistics
Total Statistics/ Male Statistics (%)		74.15	87.59	73.27	68.04	69.95	
Total Graduate/ Male Statistics (%)			15.25	35.87	17.53	5.50	
Male total graduates/ Male Statistics (%)			20.56	48.38	23.64	7.42	

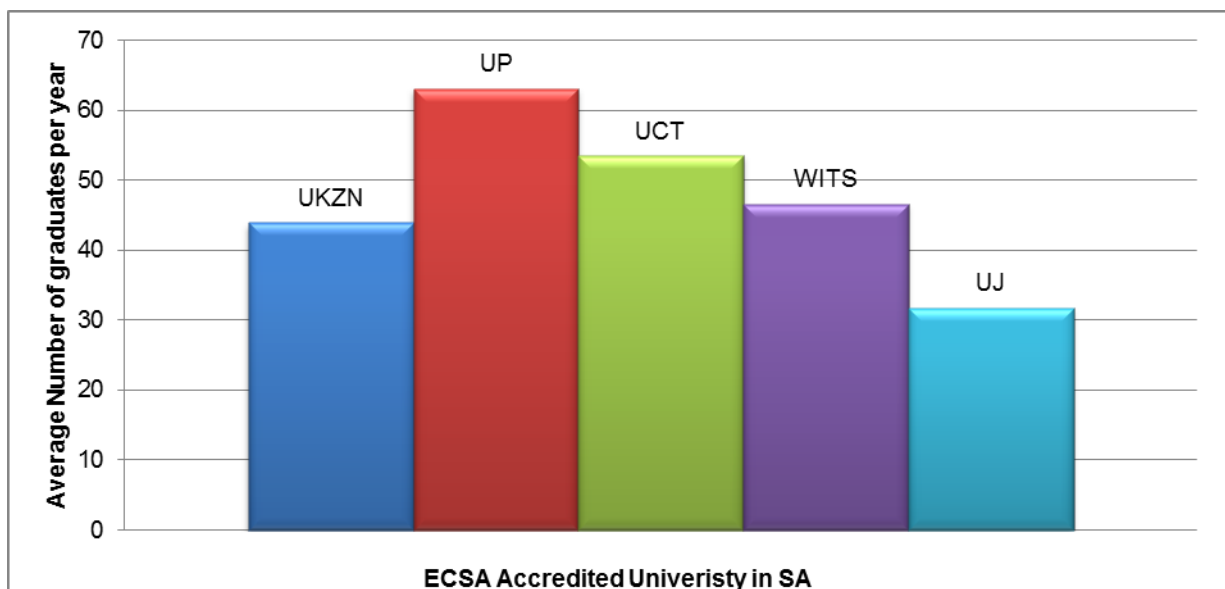


Figure 4.5: Showing the differences in average total graduates in each university.

A useful representation of data is a histogram time-series (HTS) which shows methodological movements via cross-sectional analysis (González-Rivera & Arroyo, 2012). This was very useful in depicting the change in graduate numbers from the various universities over time, as seen in Figure 4.6.

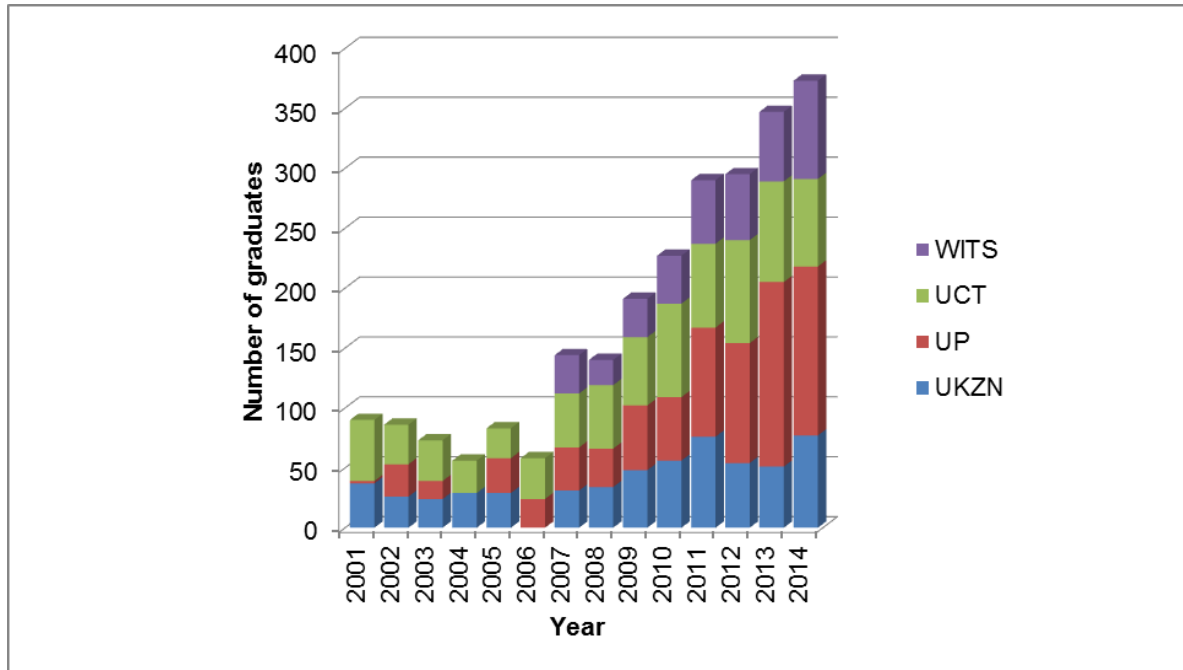


Figure 4.6: Histogram showing the variance of number of graduates per university

4.3.1.1 Trends formed from results

The trends established from the results allowed for a forecast of the increase/decrease in the number of graduates per university by finding the change in the yearly graduate values and calculating averages and the mean percentage of change. This is shown in Table 4.5.

Table 4.5: Trends formed from the study regarding the rate of change in the percentage of graduates per university per year

Graduate Numbers	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	Total	Average/ year	Average Δ univ. (%)	Average Δ / univ(%)
UKZN	37	26	24	29	29		31	34	48	56	76	54	51	77	572	44	13.07	13.39
Change in graduates		-11	-2	5	0	-29	31	3	14	8	20	-22	-3	26	69	5.75		
UP	2	27	15		29	24	36	32	54	53	91	100	154	141	758	58.31	22.01	

(Continued)

Graduate Numbers	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	Total	Average/ year	Average Δ / univ. (%)	Average Δ / univ (%)
Change in graduates		25	-12	-15	29	-5	12	-4	22	-1	38	9	54	-13	154	12.83		
UCT	51	33	34	27	25	34	45	53	57	78	70	86	84	73	750	53.57	3.16	
Change in graduates		-18	1	-7	-2	9	11	8	4	21	-8	16	-2	-11	22	1.69		
WITS							32	21	32	40	53	55	58	82	373	46.63	15.32	
Change in graduates								-11	11	8	13	2	3	24	50	7.14		

4.3.1.2 Possible spread of results

The use of statistical methods provide important aids that detect trends, ascertain relationships and deduce conclusions from data (Granato et al., 2014). The standard deviation equation is required for showcasing variance and thus providing a means to show the deviation from the mean (Lee et al., 2015). The standard deviation equation used in this study, as adapted from Lee et al. (2015):

$$S = \sqrt{\frac{\sum(x-\bar{x})^2}{n-1}}$$

S = Standard deviation of sample

Σ = Sum of sample

x = value in the data set

\bar{x} = total mean of all values

n = total number of values in the data set

The statistics were then further analysed into gender comparisons and variances via standard deviation calculated for each university per year provided foreseeable trends and drivers for future planning as denoted in Table 4.6 and Figure 4.7.

Table 4.6: Analysis of the differences and standard deviation between male and female average graduate statistics

	UKZN	UP	UCT	WITS	Average	Standard Deviation
Female	11	15	15	13	13.40	1.87
Male	33	48	39	33	38.28	7.25
Total	44	63	54	46	51.68	8.69
Difference between male - female	22	34	24	20	24.88	6.05

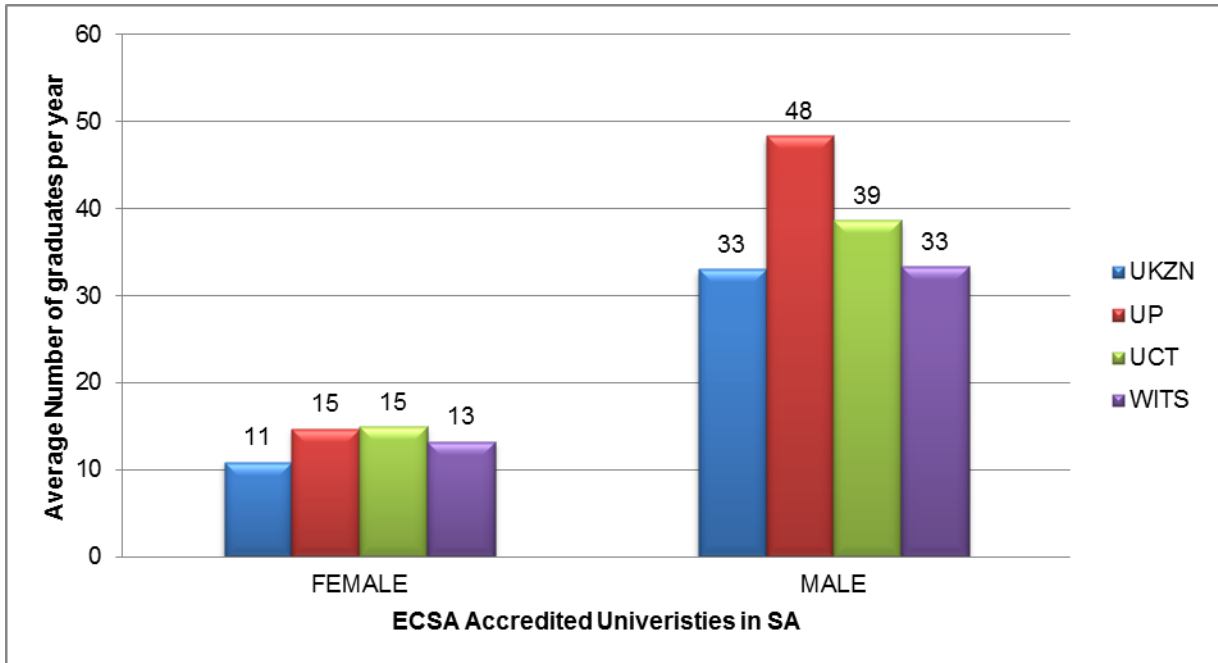


Figure 4.7: Comparison of universities average gender graduate statistics per year

The trends formed in 4.3.1.1 were integrated into the results established from 4.3.1.2 to establish forecasting into the number of graduates for future judgements. This is noted in Table 4.7.

Table 4.7: Maximum and minimum number of total civil engineering graduates that can be anticipated for future forecasting of the next 14 years (2015-2029).

	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	Total
Min	197	224	254	288	326	370	419	475	539	611	693	785	890	1009	1144	8223
Max	272	309	350	397	450	510	578	655	743	843	955	1083	1228	1392	1579	11343

4.3.2 Registered Professional civil engineers

The previous process was repeated to include only professional engineers in this comparison to highlight the current status of qualifying graduates conforming into professional status which is depicted in Table 4.8 and Figure 4.8.

Table 4.8: Average registered professional engineers per year, gender and university

	UKZN	UP	UCT	WITS	Variance	Standard Deviation
Female	1.15	1.25	1.50	0.25	0.30	0.55
Male	7.31	11.50	7.43	4.63	8.04	2.84
Total	8.46	12.75	8.93	4.88	8.755	3.39

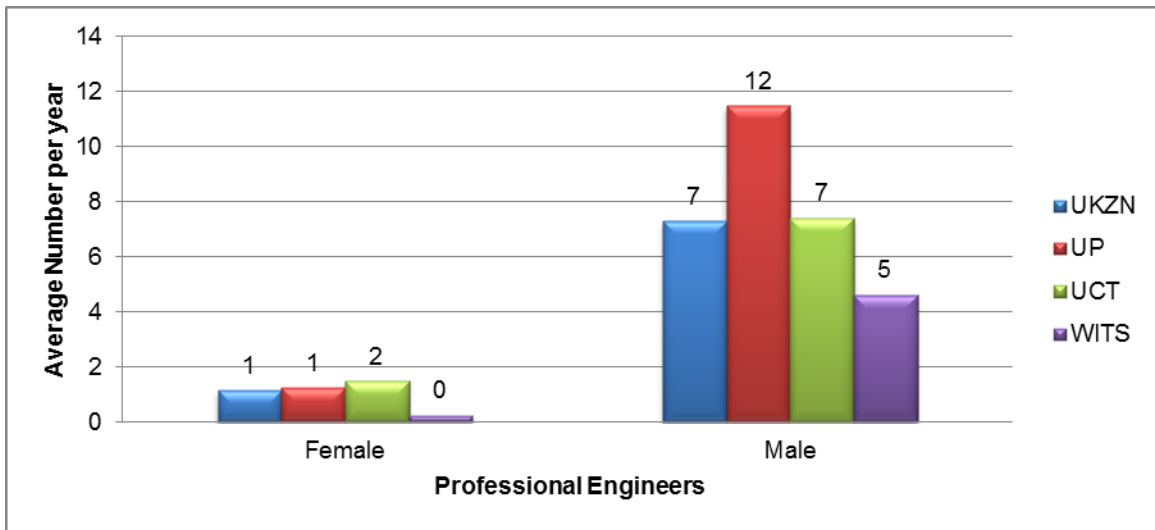


Figure 4.8: Comparison of universities average gender professional statistics per year

The differences between the other varying categories on ECSA's website is showcased in Figure 4.9 and further analysed in terms of gender differences in Figure 4.10.

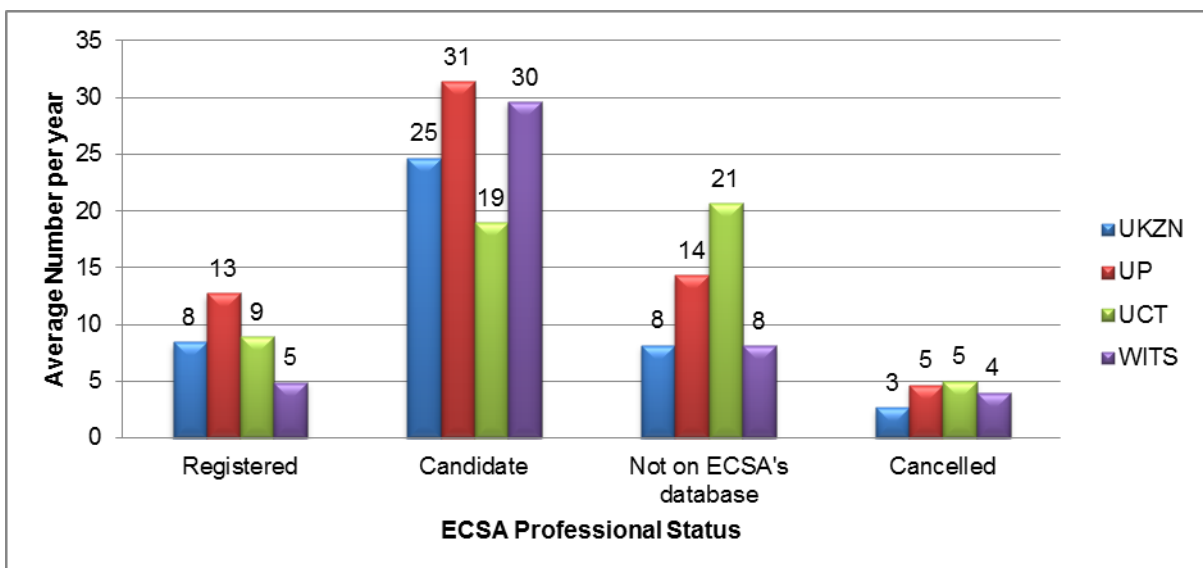


Figure 4.9: Comparison of universities average ECSA's different categories statistics of graduates per year

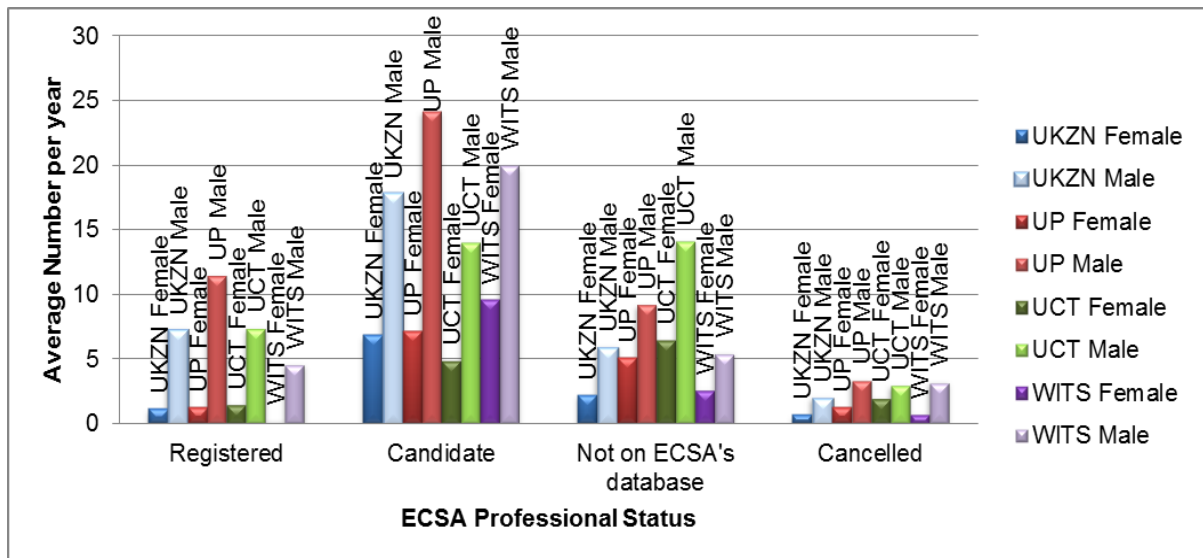


Figure 4.10: Differences in gender statistics per university and associated ECSCA category.

4.3.3 Time frames required for conversion from candidate engineer to professional civil engineer

After analysis of the current status of graduated civil engineers, an insight into the time taken to achieve professional registration and acceptance was achieved. This is summarised in Table 4.9 and further in Table 4.10 which provides the averaged values for each corresponding year and subsequent number of professionals who converted from candidate category.

Table 4.9: Time frames deduced for registration as a professional since graduation per university

Univ	No. of Reg. Pr.	Number of years taken to achieve Professional Status (years)																Total	Average
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16		
UKZN	Total	0	0	0	2	10	16	27	22	21	12	5	7	1	1	0	1	125	10
	Female	0	0	0	0	0	2	6	1	3	1	1	1	0	0	0	0	15	1
	Male	0	0	0	2	10	14	21	21	18	11	4	6	1	1	0	1	110	8
UP	Total	0	0	3	22	33	49	26	13	13	5	1	0	1	1	0	1	168	14
	Female	0	0	0	2	1	7	1	1	2	1	0	0	0	0	0	0	15	1
	Male	0	0	3	20	32	42	25	12	11	4	1	0	1	1	0	1	153	13
UCT	Total	0	0	2	1	19	26	32	22	20	7	8	4	2	2	1	0	146	10
	Female	0	0	0	0	2	5	5	3	3	1	2	0	0	0	0	0	21	2
	Male	0	0	2	1	17	21	27	19	17	6	6	4	2	2	1	0	125	9

(Continued)

Univ	No. of Reg. Pr.	Number of years taken to achieve Professional Status (years)																Total	Average
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16		
WITS	Total	0	0	0	0	10	11	13	4	3	0	0	0	0	0	0	0	41	5
	Female	0	0	0	0	0	1	0	1	0	0	0	0	0	0	0	0	2	0
	Male	0	0	0	0	10	10	13	3	3	0	0	0	0	0	0	0	39	5
Cumulative	Total	0	0	5	25	72	102	98	61	57	24	14	11	4	4	1	2	480	39
	Female	0	0	0	2	3	15	12	6	8	3	3	1	0	0	0	0	53	4
	Male	0	0	5	23	69	87	86	55	49	21	11	10	4	4	1	2	427	35
Average (%)	Total	0	0	1.04	5.21	15.00	21.25	20.42	12.71	11.88	5.00	2.92	2.29	0.83	0.83	0.21	0.42		
	Female	0	0	0.00	3.77	5.66	28.30	22.64	11.32	15.09	5.66	5.66	1.89	0.00	0.00	0.00	0.00		
	Male	0	0	1.17	5.39	16.16	20.37	20.14	12.88	11.48	4.92	2.58	2.34	0.94	0.94	0.23	0.47		

Table 4.10: Average percentage of professionals spanning various time frames (01-16 years)

	University	Number of years taken to achieve Professional Status (years)															
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
Total Average (%)	UKZN	0.00	0.00	0.00	1.60	8.00	12.80	21.60	17.60	16.80	9.60	4.00	5.60	0.80	0.80	0.00	0.80
	UP	0.00	0.00	1.79	13.10	19.64	29.17	15.48	7.74	7.74	2.98	0.60	0.00	0.60	0.60	0.00	0.60
	UCT	0.00	0.00	1.37	0.68	13.01	17.81	21.92	15.07	13.70	4.79	5.48	2.74	1.37	1.37	0.68	0.00
	WITS	0.00	0.00	0.00	0.00	24.39	26.83	31.71	9.76	7.32	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Total Female Average (%)	UKZN	0.00	0.00	0.00	0.00	0.00	13.33	40.00	6.67	20.00	6.67	6.67	6.67	0.00	0.00	0.00	0.00
	UP	0.00	0.00	0.00	13.33	6.67	46.67	6.67	6.67	13.33	6.67	0.00	0.00	0.00	0.00	0.00	0.00
	UCT	0.00	0.00	0.00	0.00	9.52	23.81	23.81	14.29	14.29	4.76	9.52	0.00	0.00	0.00	0.00	0.00
	WITS	0.00	0.00	0.00	0.00	0.00	50.00	0.00	50.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Total Male Average (%)	UKZN	0.00	0.00	0.00	1.82	9.09	12.73	19.09	19.09	16.36	10.00	3.64	5.45	0.91	0.91	0.00	0.91
	UP	0.00	0.00	1.96	13.07	20.92	27.45	16.34	7.84	7.19	2.61	0.65	0.00	0.65	0.65	0.00	0.65
	UCT	0.00	0.00	1.60	0.80	13.60	16.80	21.60	15.20	13.60	4.80	4.80	3.20	1.60	1.60	0.80	0.00
	WITS	0.00	0.00	0.00	0.00	25.64	25.64	33.33	7.69	7.69	0.00	0.00	0.00	0.00	0.00	0.00	0.00

These averages were then plotted on Figure 4.11 to illustrate the various average time frames for achieving professional status from each university.

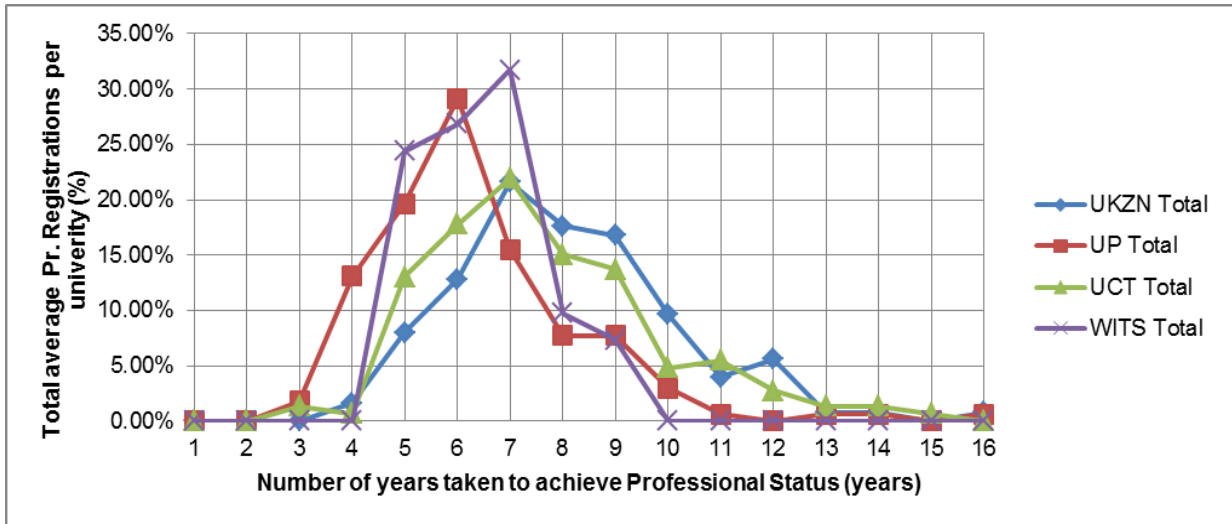


Figure 4.11: Varying time frames from graduation to professional status

The professional civil engineers were then further distinguished in terms of gender and university by means of averages as conveyed in Table 4.11 and the corresponding Figure 4.12.

Table 4.11: Summary of gender and cumulative statistics showing the average time needed to achieve professional status

	University	Min	Max	Average (%)	Average(years)	Total Average
Total	UKZN	4	16	21.60%	7	6.75
	UP	3	16	29.17%	6	
	UCT	3	15	21.92%	7	
	WITS	5	9	31.71%	7	
Female	UKZN	6	12	40.00%	7	6.63
	UP	4	10	46.67%	6	
	UCT	5	11	23.81%	7	
	WITS	6	8	50.00%	7	
Male	UKZN	4	16	19.09%	8	7
	UP	3	16	27.45%	6	
	UCT	3	15	21.60%	7	
	WITS	5	9	33.33%	7	

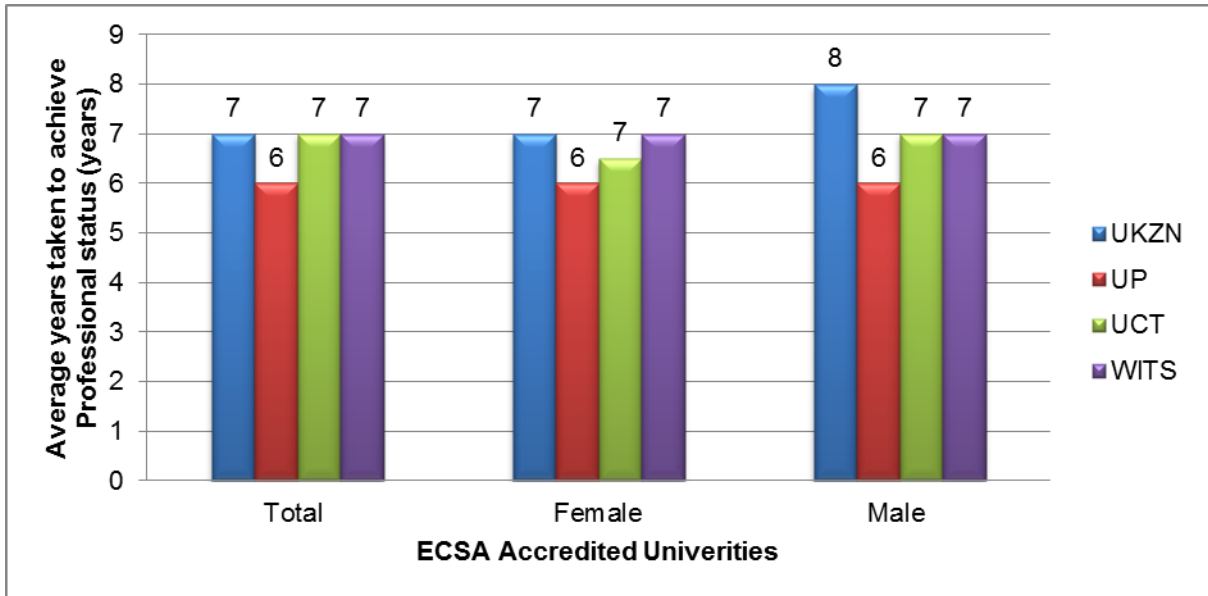


Figure 4.12: Analysis of gender specific time frames for achieving professional status

Another important comparison can be drawn from Figure 4.13 displaying the number of civil engineers that registered as professional engineers during the research study time frames.

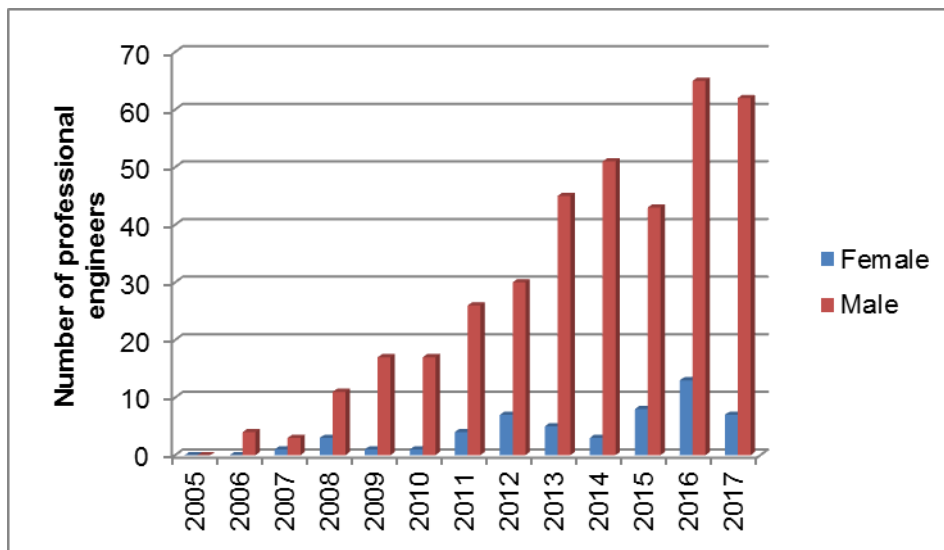


Figure 4.13: Showing the number of professional civil engineers registered per year per gender from the accredited universities

4.4 Comparison to population ratios

An important comparison to justify the study is seen in the Table 4.12 which accentuates the need for an increase in professional engineers as well as professional civil engineers. Within a time frame from 2001-2014, South Africa

managed to produce 427 professional civil engineers from 4 out of their 6 accredited universities.

Table 4.12: Summary of availability of professional engineers against population/GDP

Qualification	GDP (Million of \$)	Population	Number of registered engineers	Population per registered engineer	GDP rank	GDP per capita (Atlas rank \$)	GDP per capita (US\$)	GDP per civil engineer (US\$ million)
Total Pr. Eng	294 840.65	55 908 865	16 526	3 383	38	113	5 273.59	17.84
Civil Engineers Pr. Eng (2001-2014)	294 840.65	55 908 865	427	130 934	38	113	5 273.59	690.49

In order to forecast the number of professional engineers required to service South Africa's population in the next 11 years, an analysis into the population trends from StatsSA (2016) was established as seen in the Table 4.13.

Table 4.13: Depicting the average population increase per year

Time Frame:	Census 1996	Census 2001	Census 2011	Census 2016
Population	40 583 573	44 819 778	51 770 560	55 653 654
Difference (%)		9.45	13.43	6.98
Years		5.00	10.00	5.00
Average / year (%)		1.89	1.34	1.40
Total Average / year (%)	1.54			

4.5 Summary of results

The total summary of the number of registered professional civil engineers, graduates and candidate civil engineers and total engineer statistics from ECSA with gender comparisons is presented in Table 4.14. This allows a quick reference to easily ascertain the compressed findings of the study.

Since ECSA does not differentiate gender statistics for each race group, the female ethnic statistics was established by using interpolation from ECSA's total registered professional engineers and subsequent gender registrations percentages. As noted in the table above, 5.17 % of females are registered on ECSA's database. This percentage was then allocated according to the demographic proportioned percentages as seen in Table 4.15.

Table 4.14: Professional engineers, professional civil engineers, graduate and candidate civil engineers statistics

		Gender	No. of Pr. Eng	% Pr. Eng	Graduate	% Graduates	Candidate	% Candidates
Study Results Civil Engineers	2001-2014	Male	374	87.59	1819	74.15	880	73.27
		Female	53	12.41	634	25.85	321	26.73
		Total	427	100	2453	100	1201	100
ECSA Results	Cumulative Results	Male	15868	94.83				
		Female	865	5.17				
		Total	16733	100				
	2004-2016	Male	1873					
		Female	102					
		Total	1975					

Table 4.15: Gender based ethnic allocation based on total registered statistics

Race Group	Total registered	Total %	Female %	No. of females
Black	1857	11.10	0.57	96
White	13582	81.17	4.20	702
Indian	1105	6.60	0.34	57
Coloured	189	1.13	0.06	10

4.6 Conclusion

This chapter presented the quantitative archival data in a sequential form with graphical and tabular representations. All possible limitations and restrictions were subsequently mitigated and rationalised. It has provided a basis upon which the discussion, conclusion and recommendation can be formed.

CHAPTER 5 : DISCUSSION OF RESULTS

5.1 Introduction

This chapter will provide a comprehensive discussion of the findings found in the preceding chapter. Possible margins of errors, comparisons, ratios and trends were highlighted and examined to either concur or refute with the results of the study.

5.2 Civil Engineering graduate, candidate and professional statistics

Based on the results from Table 4.6, the average number of graduates per year is 52 persons with 25% females. During the 2001- 2014 analysis, an average of nine civil engineering graduates registered as professional engineers, with 11% being females. In summary, 17.31% of civil engineering graduates will register as a professional engineer within 13 years of completion of their degree.

The gender gap between female graduate civil engineers and female professional civil engineers was less, accounting for 25.85% of all graduates and 12.41 % of those professionally registered during the study time frames. In addition, as seen in Table 4.6 the average difference between male and female graduates per year was 25 graduates with a deviation of approximately six graduates from that mean.

The number of civil engineering graduates that register with ECSA is alarmingly low with an average of 33% not in candidate or professional status. They were either not on ECSA's database (25.76%) or cancelled their registration as candidates (7.87%). As seen in Table 4.4, the majority of civil engineering graduates who registered as a candidate engineer were males, with females representing 13.09 % (excluding those who registered as a candidate prior to converting to a professional engineer). The remaining 35.87% were male. There could be numerous candidate civil engineers who are currently in the application process to convert into professional status and unfortunately this was a limitation but could be accounted for in the standard deviations that were calculated and shown in Table 4.6 and 4.7. The average graduate and professional civil engineer statistics with standard deviations showed that a variance from the study resulted in an increase or decrease of nine graduates yearly and three professional registrations. These values were further differentiated into gender categories, resulting in a variance of two female civil engineering

graduates and 7 male graduates as well a change in 1 professional registered female and 3 male professionals correspondingly.

5.3 Comparisons with gender totals

Throughout the world there is a known bias of female employment in the workforce (Azmat & Petrongolo, 2014). The number of females in the formal sector has been relatively stagnant since January 2008, with an increase of marginal values of 2.99% as a percentage of the total work force population employed in the sector and 3.44% of the total labour force currently employed (StatsSA, 2017b).

Upon analysis of the oldest available data from ECSA regarding gender statistics, in 2008 females comprised of 2.47% of the total professional engineers in South Africa. These statistics has increased slightly to 5.17% in 2016 as seen in Table 4.14. Remarkably, the increase of 2.70% since 2008 is in line with the statistics as provided by StatsSA (2017) for the change in the number of females employed in the formal sector since 2008 being 2.99%. This then highlights the trend in 10 years that South Africa is faced with regards to this gender inconsistency. The total number of females in South Africa is currently approximately 28 406 428, which amounts for 51% of the total population (StatsSA, 2016). This figure coupled with the results show astounding shortcomings for the engineering industry and country.

As illustrated in Table 4.4, the statistics of graduate civil engineers transferring to professional status was found to be 15.25% for male graduates and 2.16 % for female graduates. Resulting in approximately 13 percentage points difference and less likelihood that a female graduate civil engineer will register as a professional as opposed to their male counterpart coupled with the 97.84% probability of a female graduate never registering at all. In addition female civil engineering graduates are approximately 10% less likely to register as a candidate on ECSA's website compared to male graduates

Approximately half of the female graduates are currently registered as candidate engineers, but 41.01% have cancelled or are not on ECSA's database at all in comparison to their male counterparts at 31.07% when compared to male civil engineering graduate numbers. There could be various reasons for these high

percentages, including the fact that many females could have changed their surnames since they graduated and as a result cannot be found on ECSA's website. In addition, deaths, changing of career paths and emigration could have factored into these statistics.

An interesting comparison is that of the percentage of professional civil engineers against the total professional engineers registered during the timeframe of the study from 2001-2017. Professional civil engineers account for approximately 21.62% of the total professional engineers registered during that period from the nine engineering disciplines that ECSA conforms with.

5.4 Race group analysis

According to Table 4.15, the Black race group has the second highest number of professional engineers in South Africa compared to other race groups, however this complement is still below 2 000 individuals compared to the 17 593 000 black labour force available at the end of the third quarter for 2017 (StatsSA, 2017b).

If the results are further scrutinised, the superimposed female black registrations percentages of the current professional registered engineers is below 100 registrations. Despite the democratic changes since 1994, within 23 years South Africa has only managed to produce 96 black female professional engineers.

Genealogically, coloured people amount to the second highest population in South Africa totalling 8.75% (StatsSA, 2016), whereas they have the least number of professional engineers registered with ECSA. A mere 1.13% as seen in Table 4.15 for total registered professional engineers concludes targets and trends that should be attended to or revisited. Indians being the minority of the population amounting to 2.47 % of the population as adapted from StatsSA (2016) have bridged a gap resulting in 6.60 % representation of South Africa's professional engineers. The white race group, 8.12% of the population still holds the most number of professionally registered engineer statistics amounting to 81%. Invariably these statistics showcase South Africa's past, however if the statistics are analysed comprehensively, a negative change in the white race group figures will undoubtedly

further decrease South Africa's chance of obtaining a higher graduate to professional rate.

Out of the 1 378 433 people above the age of 20 that has attained a bachelor's degree or higher within South Africa, 46.10% are black followed by 41.90% of white descendants (StatsSA, 2016). This does imply that from the possible degree graduates, although the majority are of Black race, there are also different degrees that can be attained highlighting that engineering is not a popular choice for them.

If the current professional registered engineer statistics per race group is compared to the country's available degree graduates, the Black race group who chose engineering amount to 0.29 %, the Coloured race group was 0.25%, the White race group was 2.35% and the Indian/Asian race group amounted to 1.24%. This indicates that all race groups tend towards other fields of study other than engineering. These statistics include both genders and reiterate the further minimal inclination for females to choose engineering.

The results of the racial analysis could be subject to variances since the yearly changes in racial demographic registration could be depicting a different pattern that suggests a further in-depth study relating to the racial demographic changes and requirements going forward.

5.5 Analysis of universities

To ensure accurate comparisons between the participating universities, averages and standard deviations were inferred for a comprehensive view to address any discrepancies that may have occurred during the study.

5.5.1 Civil Engineering graduate statistics

As seen from Table 4.4, the University of Pretoria (UP) produces the most civil engineering graduates per year; together with achieving the highest rate of increase in graduate numbers at 22.01% per year as noted in Table 4.5. Through detailed analysis of the next highest average number of graduates, it was found that because UCT had constant high levels of graduates being produced, their rate of increase was minimal at 3.16% when compared to the other universities. WITS and UKZN

had similar average graduate numbers. The differences in the rate of change in graduates also tied up with the average number of graduates they produced per year showing a similar trend amongst them.

As exemplified in Table 4.6, the differences between male and female graduates were relatively similar amongst all universities and even though South Africa's population is equally split between genders, there are still approximately 3 males for every female that graduates as a civil engineer. WITS had the largest percentage of average female graduates per year amounting to 28.26%, shadowed by UCT with 27.78%, UKZN and UP at 25.00% and 23.81% correspondingly. The results of UP requires some attention due to their high levels of civil engineering graduates as well as their high rate of increase in graduates per year but low female quantities.

Taking into account the standard deviation from the results in Table 4.4, a maximum upper limit of approximately 60 graduates are being produced yearly per university coupled with the lower limit of a possibly a minimum of 43 civil engineering graduates being produced yearly. This amounts to a range of 172-240 civil engineering graduates per year.

5.5.2 Professional civil engineer statistics

Relative to the highest number of graduates produced at the University of Pretoria, similarly they have produced the highest average number of registered professional engineers per year compared to all the universities with an average of 20.24% of graduates becoming a professional civil engineer.

An interesting result was that of the University of KwaZulu-Natal which produced a significantly higher average total of professionals as opposed to having the lowest average graduates produced per year. UKZN's average graduate to professional conversion rate is 19.23 %, followed by UP at 16.54% and lastly WITS with 10.61%. With a yearly average of approximately 9 professional engineers per year per university and including the standard deviations, the maximum and minimum South Africa can produce is 49 and 13 professional civil engineers respectively.

There are approximately 7- 8 males for every female that registers as a professional civil engineer on average per university per year. UCT averages the most females being registered with 16.8% representing the female complement of total registrations, followed by UKZN with 13.59% female percentages.

The results for the University of Pretoria imply that although they have the highest average generation of graduates, they also have the lowest percentage of females that are graduating as well. Coupled with attaining the second lowest average of female professional civil engineers is concerning.

5.6 Timeframes needed for registration as a professional civil engineer

A major concern facing the engineering industry is the time frames required for attaining professional status. As per Policy Statement R2/1A, the minimum number of years post graduating in any field of engineering is three (3) to be competent enough to apply for professional recognition (ECSA, 2017b).

The average years for registrations was determined by ascertaining the maximum number of conversions occurring during a specific year, throughout the entire time series of the study as seen in Table 4.9. This was then reiterated for each university and cumulative average totals calculated.

As found from the results shown in Table 4.11, collectively it takes an average of 6.75 years or 81 months for candidate civil engineers to become professionally registered as averaged from all the universities. It must be noted that the process of applying includes a varying time frame of administration that can occur between 6-12 months. The female conversion rates are perceptibly lower than male conversion rates due to the male total averages being exceedingly higher. As per Table 4.11, the minimum time (3 years) and maximum time (16 years) was fulfilled by male civil engineers. The shortest average time frame amongst all the universities was a period of 6 years, that was produced by the University of Pretoria with 27.45% males and similarly 46.67% females achieving professional status in that duration. UKZN's male graduates took the longest to transfer to professional status with an average of 8 years that was required.

The remaining universities' graduates all required similar time periods to accumulate enough post-qualification experience to register as professional civil engineers. These time frames could be dependent on various factors that include:

- Incomplete or deficient applications that are returned for resubmission which increases time frames due to non-conformance with the prescribed ECSA standards for professional engineers' competencies. This was addressed in Chapter 2. ECSA believes that the quality of candidates' applications mirrors directly on their competence and professionalism.
- Due to the engineering industry being very diverse, the different career paths that can be pursued whilst still in the engineering fraternity will directly result in a graduates' experience being completely all-encompassing which enables him/her to register quickly because all outcomes are fulfilled or the opposite.
- A country's economy has a relative effect on the chances/ ability of a graduate in gaining sufficient experience since various projects and infrastructure is dependent on the available budgets and economies growth rate. An example was the 2010 World Cup which produced ample work/experience for various sectors including civil engineering.
- The lack of adequate information of graduates who were not on ECSA's database possibly due to surname changes or other reasons.

If timeframes are taken cognisance of, it would indicate that to wait 7 years for a graduate civil engineer to register as a professional, is almost a decade too late inclusive of their studying timeframe (minimum 4 years). Graduate numbers needs to increase and the time taken to achieve professional status inadvertently shortened if possible. This can become possible if graduates are forced to convert their candidate status into professional as soon as possible.

5.7 Government targets

The latest legislation for the South African National Policy Framework for Women empowerment and gender equality (WEGE) strives for a fifty per cent female complement in the executive board of every organisation (Hills, 2015). The other strategies that affect the formation of quota decisions as well as behaviours are the

BBBEE (Broad-Based Black Economic Empowerment) scorecard programme (Kleynhans & Kruger, 2014).

According to the Codes of good practice on Broad Based Black Economic Empowerment, the Employment Equity and Management Control is merged into one namely Management Control element (DTI, 2016). The number of black female employees in professionally qualified and experienced specialists and midmanagement should be 38% of all employees to comply with the skills development targets for the new scorecard (DTI, 2016). These are especially valid for large companies' greater than R 50 million which require full compliance (DTI, 2016). Since there are over 540 companies registered in CESA (Consulting Engineers of South Africa) with over 24 300 employees, the resultant requirement of 9 234 black females in professionally qualified roles is needed.

5.8 Sustainable global competitiveness targets

Comparisons have been made from Table 2.7 relating to the required average population per engineer ratio found by the average of the English speaking countries that are signatories of the Washington Accord, i.e. UK, Canada, USA, Australia, Ireland and New Zealand which averaged a ratio of 259:1. South Africa's current population per engineer ratio of 3383:1 is significantly far behind. In order to get to the target an increase of 199 338 professional engineers is required to cater to the current population statistics. From discussions above, civil engineering accounted for 21.62% of the total professional registrations from ECSA, hence another 43 097 professional civil engineers will be required to service the current population.

Based on a 1.54% population increase per year from Table 4.11 and taking into account the current trends as established in the study over the last 14 years (2001-2014) as well as *ceteris paribus*, in 2029 South Africa will have an estimated population of 66 815 752. This would require 257 976 professional engineers (excluding any current statistics) and approximately 55 775 professional civil engineers based on the 21.62% proportion as previously established from the study.

5.9 Forecasting of graduate civil engineers and professional civil engineers

Within 14 years and at the current average rate as established in Table 4.5 of 13.38% increase per year per university, there will be a minimum of 8223 civil engineering graduates produced from 2015-2029 together with a maximum forecast of approximately 11 343 graduates (as noted in Table 4.7).

The change in professional engineers from 2002-2016 as taken from ECSA was calculated to be 12.23% in those 14 years. If this value is utilised to forecast the number of professional engineers for the next 14 years until 2030, there will be 18 779 professionally registered engineers in South Africa.

Even though the statistics for the professional engineers was extended to 2030, the forecast is still below the requirements necessary to fulfil targets for 2029 which was 257 976 professional engineers. The female figures were drawn from the established change in 2.70% since 2008 to current a 5.17% of the total professional engineer statistics. Hence of the forecasted professional engineers, females will amount to around 1 985 using an increase of approximately 10.57% which was optimistic (5.17%+2.7% (8 years) + 2.7% (8years)).

If the current total black professional engineers statistics is interpolated, there would be 2 085 black professionals. This is further separated into black females at 0.57% which indicates only 107 female professionals will be available.

Since civil engineers account for 21.62 % of the total engineers, their estimates are roughly 4 060, that will be available in 2030. This is still well below the required 55 775 to get to a sustainable international standard. Notwithstanding the fact that there is a gender deficiency in the engineering fraternity with emphasis in civil engineering, there is an even greater deficiency in professional engineers cumulatively in the country. This is irrespective of race or timeframes required to gain their professional status. Although engineering is centralised towards technical excellence and ensuring mathematics and sciences is progressive, the profession must also become introspective and look at how engineering can affect the greater community at large and how important the need for a drastic increase in the professions statistics have proven to be (Florman, 2014).

5.10 Conclusion

The registered professional engineer statistics have proven unequivocally the analogous relation to the current state of affairs faced by South Africa. The number of female professional engineers in South Africa is dramatically low, and similar results were found for the civil engineering industry. This could also be contributed to the long time frames needed for graduates to convert to professional status and the exploration into civil engineering graduates and conversion rates provided a means to understand these timeframes and for future forecasting. The gender related results concurred with the international findings as addressed in Chapter 2.

CHAPTER 6 : CONCLUSION AND RECOMMENDATIONS

6.1 Introduction

Numerous professional engineering organisations have enunciated the need for a more holistic type of engineer that can deal with multifarious social issues forthcoming in the future and have further requested that the educational structure and system tutor to that class of engineer (Canney & Bielefeldt, 2015). Moral reflexive practise allows transformative learning which can assist in engineering graduates understanding that social responsibility is both personal as well as professional (Hibbert & Cunliffe, 2015). This will assist in developing both the country's gender deficits and ensuring the current engineering graduates take responsibility to change the industry they are entering by means of endorsement and mentoring of younger possible scholars to enter the field of engineering. It has now been proven that businesses who have a substantial amount of women employees throughout all organisational levels, have a tendency to outperform the businesses who are predominantly male (Cotterell, 2017). There is currently no quota's strictly requiring female professional engineers in companies or municipalities. The Employment Equity Act is generally followed regarding gender inequality and still cannot be met within engineering arenas.

6.2 Concluding the aim and objectives

6.2.1 Aim of the study

'The aim of the study was to determine the current statistics of professional engineers and to synthesise and critically interrogate the 2001-2014 graduate and professional civil engineer statistics. Cross examination into well performing universities was done via comparative studies analysis; in addition timeframes needed to convert to professional status was investigated together with gender comparisons'.

The aim was fragmented into essential research areas that were investigated and these areas were fulfilled by the research objectives. Therefore by achieving the research objectives, the aim of the study was concluded as a result.

6.2.2 Objectives

6.2.2.1. Objective 1

'To investigate the process of how candidate engineers transfer to professional status and to examine the professional engineer statistics'.

In addressing this research objective, the process of transferring to professional status was explored from ECSA's requirements as well as international practises as available in the literature review. The current professional statistics were established from ECSA's database showcasing all disciplines in engineering with gender and racial comparisons. The findings showed that there are 3226 people to service for every professional engineer in South Africa. Female engineers account for a mere 4.34 % of the total professionally registered engineers, hence there will be 74 306 people to be serviced by one female engineer. Further racial comparisons were compiled to highlight the scarcity of professional engineers irrespective of their discipline.

6.2.2.2. Objective 2

'To establish the graduate civil engineer statistics from 2001-2014'.

Graduate information was gained from four out of the six ECSA accredited universities in South Africa. The raw data was then condensed into cumulative totals and hence averages were calculated due to the varying provision of archival data of the graduates from each university. The study revealed a maximum of approximately 60 graduates are being produced yearly per university coupled with a minimum of 43 civil engineering graduates being produced yearly. This amounts to a range of 172-240 civil engineering graduates per year.

6.2.2.3. Objective 3

'To determine the professional civil engineer statistics from 2001-2014'.

As mentioned in Objective 2, graduate lists were collected from the universities spanning the 14 year time frames and the surnames of each graduate were inputted into ECSA's database. Every registered engineer can be identified by their surname on ECSA's website. The results depicted a yearly average of approximately nine (9)

professional engineers per year per university and including the standard deviations, the maximum and minimum professional civil engineers South Africa can produce is 49 and 13 respectively. The study highlighted that there are approximately 7- 8 males for every female that registers as a professional civil engineer on average per university per year.

6.2.2.4. Objective 4

‘To establish time frames (trends) relating to conversion from candidate civil engineer (graduate) status to professional status, henceforth highlighting gender and university based differences’.

During the 2001- 2014 analysis, an average of nine (9) civil engineering graduates registered as professional engineers, with 11% being females. In summary, 17.31% of civil engineering graduates will register as a professional engineer within 13 years of completion of their degree. The statistics of graduate civil engineers transferring to professional status was found to be 15.25% for male graduates and 2.16 % for female graduates. Female civil engineering graduates are approximately 10% less likely to register as a candidate on ECSA’s website compared to male graduates. The University of Pretoria produced the highest average number of registered professional engineers per year compared to all the universities. UCT averaged the most females being registered. It became apparent that the admission and retention of females in both engineering institutes and in the work place is undesirably low and depends on many variable factors as highlighted in the Chapter 2 and Chapter 5. The research into gender differentiation and gaps in knowledge were revealed showcasing the lack of information in South Africa regarding the graduate and professional statistics and studies.

6.2.2.5. Objective 5

‘To highlight gender equality standards/requirements and forecast any trends to achieve these requirements’.

There is currently no quota’s strictly requiring female professional engineers in companies or municipalities. The Employment Equity Act is generally followed regarding gender inequality and still cannot be met within engineering arenas. From

the statistical analysis, it was forecasted that there will be a minimum of 8223 civil engineering graduates produced from 2015-2029 together with a maximum forecast of approximately 11 343 graduates. The number of professional engineers forecasted until 2030, was 18 779. Civil engineers accounted for roughly 4 060 of that total. This is still well below the required 55 775 to get to a sustainable international standard. Notwithstanding the fact that there is a gender deficiency in the engineering fraternity with emphasis in civil engineering, there is an even greater deficiency in professional engineers cumulatively in the country.

6.3 Limitations and recommendations for future studies

South Africa's socio-economic development and the general wellbeing of its citizens largely depends on the efficient sustainable operation, maintenance and supply of engineering organisational structures (Ashpole, 2016). The demand and supply of female engineers is very unbalanced and with the current trends that have been formulated, the ability to fulfil these demands worsen with time unless measures are implemented to alleviate the situation going forward. The engineering profession has proved to be largely male dominated as seen by the current male professional engineers complement as well as the number of civil engineering graduates being produced. These values are independent of South Africa's history and are noted throughout the world within all the Science and technology related fields as described in Chapter 2. The overwhelming fact that all racial groups are lacking numbers in terms of female civil engineers and professional civil engineers is indisputable. This further extends to all professional engineers. More research needs to be done to further solidify this cause since this topic is not well documented and researched. The consequential research found whilst undertaking this research resulted in the following future studies recommendations:

6.3.1 ECSA related themes

Legislation regarding the extent that the Engineering Profession Act provides regulation of the engineering profession must be reviewed and updated to allow ECSA with more authority. ECSA needs to provide timeframes to become professional engineers and "cut off" timeframes for the allowance of entering candidate status upon graduation. This should force graduates to immediately become registered. Following studies in international countries as found in Chapter

2, an increase in mentors to be employed at the various engineering firms to ensure an increase in professional applications since experience will be monitored and progressive. This allows ECSA to maintain their high standards for registration, thereby ensuring our alliance and acceptance into the Washington Accord remains. There should be no compromise with regards to the acceptance standards in order to superficially increase professional engineer statistics. This was noted when SAICE submitted an application against ECSA to the high court regarding changes in the board and review panels for professional engineer registrations (Oliveira, 2017). SAICE wanted the current council members of ECSA suspended (Oliveira, 2017).

6.3.2 Employability research

Although growth in professional engineers' statistics is desirable in all genders and all engineering sectors, research into tangible availability of employment is necessary especially since South Africa's current economy is going through a recession in conjunction with many industries showing declining employment statistics. As stated by StatsSA (2017a) in the third quarter of 2017, the construction industry faced retrenchment which is a direct indicator for the civil engineering profession, again alluding to the need for a study relating to the impact of the economy on the engineering profession and the sustainability of a rapid increase in professional engineers if attainable.

6.3.3 Race/ gender research

Through the study it was noted that more research needs to be conducted to decipher changes and reasons for different race group preferences in tertiary courses. Gender studies regarding the reasons for the engineering statistics and movement of current female professional engineers should be initiated.

6.3.4 Inclusion of all ECSA accredited institutions and categories

More cross sectional studies into all universities and institutes of technology can provide more information to the engineering community about the different professional engineering timeframes and statistics gathered since it will constitute all the accepted educational institutions and engineering disciplines by ECSA. A comparison of the various engineering disciplines can be formulated showcasing industry specific requirements necessary for the future.

6.3.5 Change of trends in addition to quotas

Taking cognisance of the results from the study, the deficiency in both professional civil engineers and professional engineers in all disciplines is profound. Further to this, the gender divergence found in graduate numbers and professional engineers (total and that of civil engineers) shows trends that will not be able to fulfil targets as required by South African government regarding elevating female numbers. According to Cotterell (2017), whenever there are major inequality issues surfacing in a country, structured quota by either incentives or actual enforced protocols become very useful in assisting gaining targets.

6.3.6 University drop out factors

There is a vast amount of engineering undergraduates who do not become graduates and these high rates of drop out needs to be addressed (Meyer & Marx, 2014). There needs to be follow up studies trying to understand the reasoning behind the low retention of these undergraduates. Possible investigations could include longitudinal studies with exit interviews of undergraduates who are leaving and/or comparisons of pass rates with decisions to leave an intended field of study.

6.4 Conclusion

In addressing the research questions of this study, many other congruent issues were discovered and recommended for future inclusion into studies. It is of the authors' opinion that the aim of the study was fulfilled covering all pertaining objectives and providing substantial information to the specific audiences.

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APPENDICES

Appendix A: Processed statistics

Appendix B: Ethical Clearance Approval Letter

Appendix C: Turnitin Report