

THE STATUS AND CHALLENGES OF INDUSTRIAL ENGINEERING IN SOUTH AFRICA

Prof Corné Schutte
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BIOGRAPHY

Prof Corné Schutte was born in 1963 as the eldest of three children and spent his childhood on a farm in the Lowveld. He matriculated at Bergylam High School in Nelspruit in 1981, with seven distinctions. His tertiary studies culminated in the following qualifications: BEng in Industrial Engineering in 1985, BEng(Hons) in Industrial Engineering in 1986, and MEng in Industrial Engineering in 1988, all obtained cum laude at the University of Pretoria.

In 1989 he joined Paradigm Systems Technology in Pretoria and began a career in industry. Initial projects to which he contributed were done for the South African Air Force, but the company also became involved in marketing its products and services internationally. Prof Schutte joined the international marketing team of the company, and became involved in projects in France and the United Kingdom.

As a consequence, his services were also used for a project for the Sabre Group in Texas, USA, with Cathay Pacific as a client in 1997, and later also for BAe Systems in the creation of a joint venture with IFS.

In 1999 he relocated to New Mexico, USA, to join a small software development company in order to develop products for civil aviation markets. The initial clients were Cathay Pacific and Virgin Atlantic, and this again led to the opportunity to work in various locations around the world, ending in Hong Kong in 2004.

Prof Schutte returned to South Africa at the end of 2004 and joined Stellenbosch University as a senior lecturer in 2005. He completed his PhD at Stellenbosch University in 2010, and was promoted to associate professor in the same year.

Meanwhile he had become involved in the Southern African Institute for Industrial Engineering (SAIIE) in 2007, where he started by organising the annual conference, and ended up as the president of the Institute from 2009 to 2011. He currently still serves on the council, and is a director of SAIIE.

At present he is a professor and chairman of the Department of Industrial Engineering at Stellenbosch University, and his current research focuses on innovation, knowledge networks, engineering management and lately also on the status of industrial engineering in South Africa.

He is the editor of the *South African Journal of Industrial Engineering* (SAJIE), an ISI accredited journal.

He is married to Rene and has three children: Anthony, a 21-year-old stepson, Christian, a very busy toddler, and Kiara, a girl in foster care. They spend their time as a family in Betty's Bay over weekends and holidays, and in Somerset West during the week.

THE STATUS AND CHALLENGES OF INDUSTRIAL ENGINEERING IN SOUTH AFRICA

ABSTRACT

The industrial engineering discipline in South Africa was examined firstly by introducing the context of the discipline in South Africa, secondly by revisiting the history of industrial engineering in the country, thirdly by considering the changing political and economic landscape of South Africa, and finally by analysing the discipline in terms of the following aspects: university studies and qualifications, employment in the industry sectors, race and gender profiles, utilisation and competence in the industry, and income profiles. The analysis was based on a recent survey sent to practising industrial engineers, on the membership data of the Southern African Institute for Industrial Engineering (SAIIE), and on two internal SAIIE investigations – one done for the Strategic Integrated Project Skills Requirements Initiative and another regarding the suitability of the Industrial Engineering National Diploma (NDip) and the Bachelor of Technology (BTech) programmes in South Africa.

The study concluded that racial transformation has not been successful so far, and that most black industrial engineers have technical qualifications (NDip and BTech), while most white industrial engineers have academic qualifications. This limits the utilisation of black industrial engineers and, as a consequence, also the success of their careers and their distribution in the industry. This in turn hampers transformation initiatives.

INTRODUCTION

Industrial engineering as a discipline has evolved worldwide into a major engineering and management discipline. The effective utilisation of industrial engineering has contributed to an enhanced standard of living through increased productivity, improved quality of work, better quality and nature of services, and improvement in working environments [1].

The Institute for Industrial Engineering (IIE) defines industrial engineering as follows (the definition does not differ remarkably from that of the Southern African Institute for Industrial Engineering (SAIIE) [2]:

Industrial engineering is concerned with the design, improvement and installation of integrated systems of people, materials, information, equipment and energy. It draws upon specialized knowledge and

skill in the mathematical, physical, and social sciences together with the principles and methods of engineering analysis and design, to specify, predict, and evaluate the results to be obtained from such systems. [3]

Industrial engineers (IEs) are thus responsible for the optimal design, implementation, integration, operation, improvement and management of high-level systems. Such systems typically consist of chemical, electrical, electronic, mechanical or civil components. These high-level systems generally exist within organisations as a mixture of equipment, information, people, capital, policies, processes, etc. IEs optimise these systems to improve quality and productivity, and to reduce costs. Industrial engineering is a broad professional engineering discipline involving the design of effective systems and procedures. Such systems use the basic resources of transformation systems (people, machines, material, IT-systems, capital and entrepreneurial spirit) in organisations. Human and physical resources are thus combined and integrated to achieve specific objectives in these organisations [4].

Any engineering discipline follows technological trends, and the scope and focus therefore adjust to these changing trends. Similarly, in industrial engineering, technology trends have had a major influence on how IEs are used in the industry, and this has caused industrial engineers to reflect on the changes in the past. An example was the Information System Revolution of the 1990s, where industrial engineering was one of the first engineering disciplines to realise the enormity of the impact of information systems. This, as a consequence, resulted in an identity crisis for industrial engineers, who were caught between the Industrial Revolution and the new challenges of the Information System Era [5].

In addition, within the South African context where major socioeconomic changes have occurred since 1994, industrial engineers have been exposed to a number of unique challenges that are non-existent or less dominant in other fields.

This paper examines the status of industrial engineering in South Africa, highlights the unique challenges that this discipline faces, and suggests ways forward to address some of these challenges.

THE HISTORY OF INDUSTRIAL ENGINEERING IN SOUTH AFRICA

The need for industrial engineers in South Africa arose with industrialisation in South Africa, when major industries such as ESCOM (as it was then known) and ISCOR were established in the 1920s. World War II – a time of restricted imports – helped to advance industrialisation. This led to more sophisticated requirements in order to manage mass production and more sophisticated manufacturing technologies. In addition, in 1940, the Industrial Development Corporation of SA Limited (IDC) was established, by Act of Parliament, with the main objective of promoting the establishment of industrial undertakings and the development of existing enterprise on sound business principles. The IDC assisted and pioneered many industries, the most notable being SASOL's oil-from-coal project [6].

The increasing number of skilled people drawn to the steadily-developing manufacturing industry eventually created the need for a collective formal body representing what were then referred to as 'production engineers'. The nomenclature later included the term 'manufacturing engineers'. The South African Association of Production Engineers was formed in 1943. This led to the launch of the South African Institute of Industrial Engineers (SAIIE) at the end of 1981. SAIIE was given impetus in 1984 when it was acknowledged as an institute in terms of engineering legislation, and the industrial engineering profession was then recognised in South African law as a separate branch of engineering [6].

The development of industrial engineering as an academic discipline in South Africa took place as follows [6]:

- The University of Pretoria introduced the first industrial engineering graduate course in 1961, producing the first industrial engineering graduates in 1964. By 1967 the University of Pretoria had established the first Department of Industrial and Systems Engineering in South Africa.
- At the University of the Witwatersrand, a chair in Industrial Engineering was established in 1969. Graduate industrial engineers emerged from the University in the late 1970s, and the first black African industrial engineer graduated in 1984.

- Stellenbosch University introduced graduate courses in industrial engineering and manufacturing technology in the late 1970s, followed by the founding of a Centre for Robotics and the Department of Industrial Engineering in 1985.
- Other South African educational institutions, including technikons and universities of technology, followed the trend by offering full industrial engineering courses.

The study of industrial engineering now culminates in an academic qualification (BEng) at four academic universities, and in technical qualifications (BTech and NDip) at all the technical and comprehensive universities in South Africa.

SOUTH AFRICAN INDUSTRIAL ENGINEERING APPLICATION DRIVERS

Technology Trends

One way of determining the current level of technology uptake in a discipline is to compare the research in the country with worldwide trends. This can be achieved by analysing the scope and trends of the research published in international, compared to regional, journals.

Dastkhan and Owlia [7] analysed the trends in international IE research over the three decades up to 2007. The publications on different IE topics from four main international publishers – Pergamon, Elsevier, Springer and Emerald – were studied. Data derived from 7 114 papers were analysed and categories were defined through a survey of keywords in the publications, themes of IE conferences, and ideas of experts in this field. The analysis showed that the proportion of publication outputs on production management had decreased from 1997 to 2007, while research on topics like intelligent systems, supply chain management, and information technology had increased. As a result, the researchers expressed an expectation that, in an international publication context, most future IE research would be focused on subjects like information technology, intelligent systems, optimisation, quality, and supply chain management.

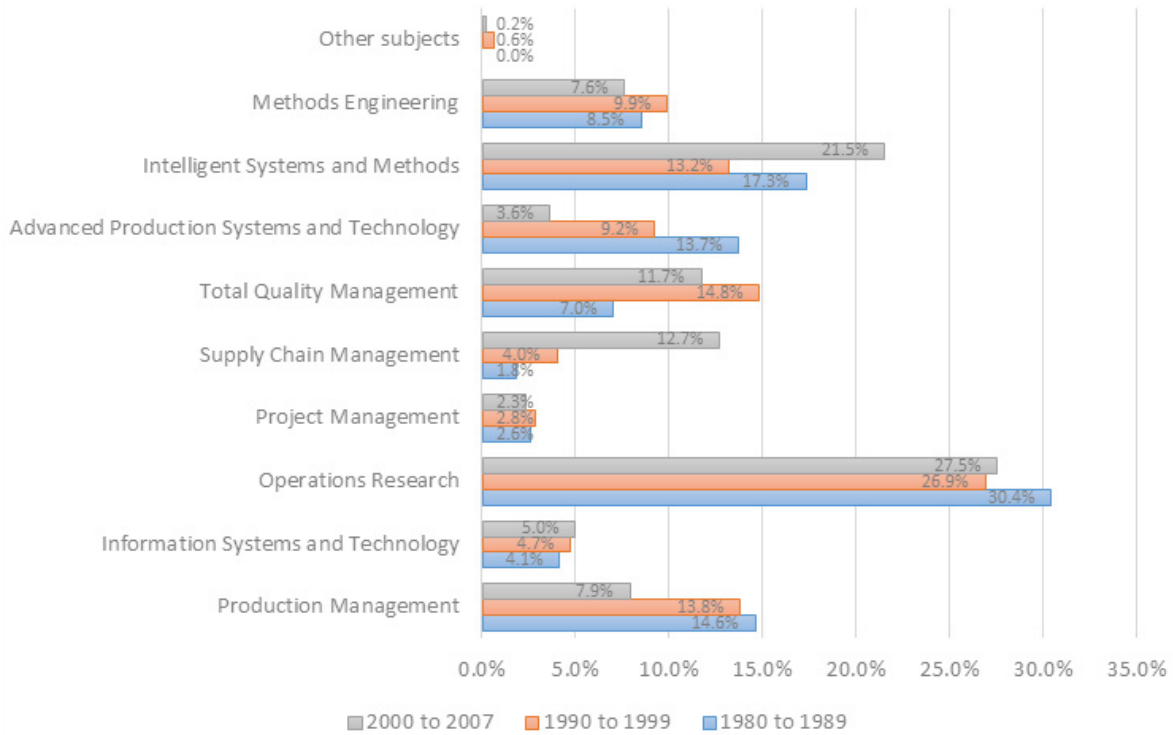


Figure 1: Proportion of research on different IE topics in international publications – Source: Adapted from Dastkhan et al. [7]

For similar reasons, an analysis was performed on the *South African Journal of Industrial Engineering* (SAJIE) in 2010. At that time, a textual library of 283 journal articles capturing a 22-year history was available for a semi-automated textual analysis using Latent Dirichlet Allocation (LDA), a statistical topic model technique [8]. The result of this study is shown in Figure 2.

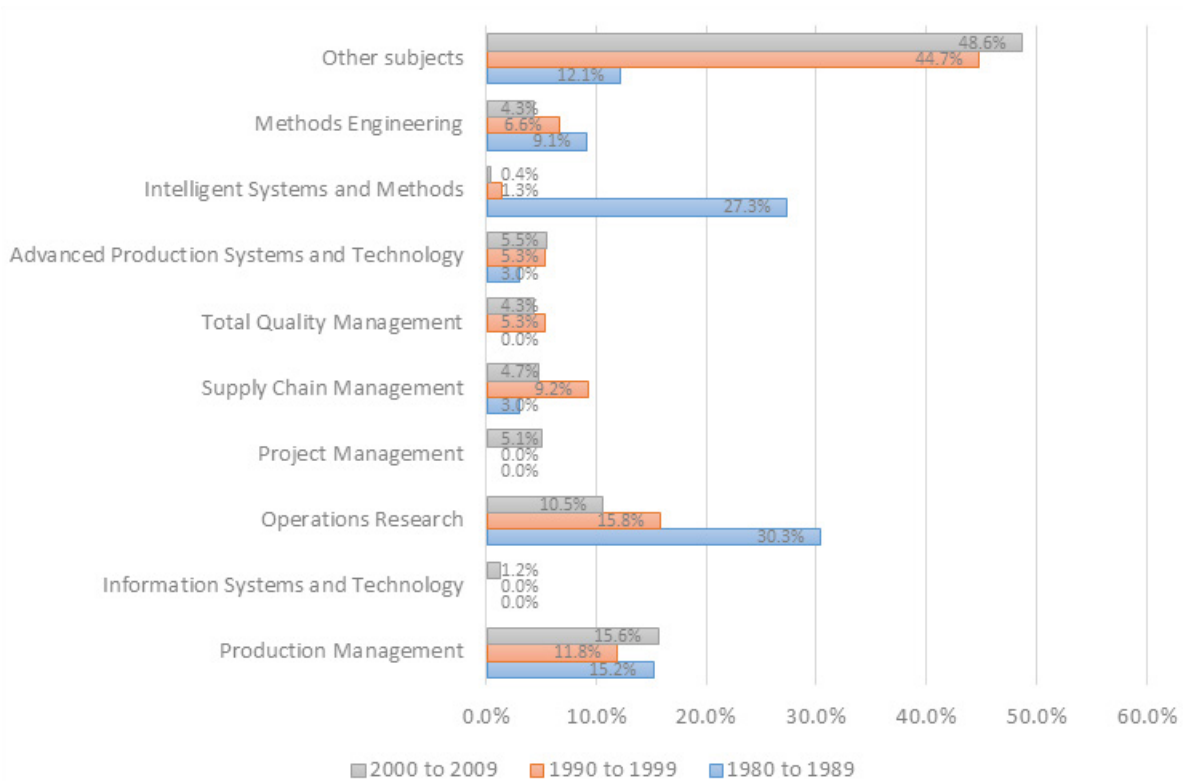


Figure 2: Proportion of research on different IE topics in SAJIE (LDA topic model approach) – Source: Adapted from Uys et al. [8]

A successful comparison of the results of the two studies therefore lies in the ability to relate and interpret Figure 1 and Figure 2. For instance, Figure 1 indicates that 26,9% of all articles written across the international spectrum between 1990 and 1999 were in the category of Operations Research. From a South African perspective, Figure 2 indicates that during the same period 15,8% of articles in the SAJIE articles corresponded with the Operations Research category.

The most significant difference is the high percentage of 'Other subjects' found in the 1990–1999 and 2000–2009 periods in Figure 2. Each of the 50 SAJIE topics not allocated to one of the nine specific categories determined by Dastkhan and Owlia [7] was grouped under 'Other subjects'. Most of these topics are more management-oriented, which may be attributed to the fact that the SAJIE also publishes articles in the fields of engineering and technology management (ETM).

Relating the results from the two studies can be simplified by reducing the ETM influences in the SAJIE research outputs by removing the 'Other subjects' category from the comparison. The 'Other subjects' category in itself only constitutes 0,2% of international IE trends from 2000 to 2007; so the omission of this category for the purpose of comparison is justified. Figure 3 shows the recalculated SAJIE percentages across the nine specific categories, pairing the 2000–2009 series from Figure 1 and Figure 2, thereby objectively comparing the recent articles of this study with the study done by Dastkhan and Owlia [7]. This was also combined with another analysis done the following year [9], similarly using LDA on the well-known journal

Computers and Industrial Engineering (CaIE). These results are shown in Figure 3.

By comparing the respective percentages of CaIE to that of international study, it can be seen that CaIE closely corresponds with international study in terms of the categories used by Dastkhan and Owlia [7], with the exception that CaIE seems to have a much stronger coverage in the Operations Research category and less coverage in the Total Quality Management and Intelligent Systems and Methods categories. This is probably not a surprising observation as each journal builds a reputation regarding a focus area over its lifetime, which is determined by the preferences of the editorial board and authors who have published in the journal. This shows in CaIE articles and their stronger Operations Research focus compared to other IE journals.

However, from Figure 3 it is evident that, aside from ETM research, the main South African IE research area in recent publication history was Production Management, followed by Operations Research, and Advanced Production Systems and Technology. Internationally, however, Operations Research was the primary IE research publication area, followed by Intelligent Systems and Methods, and Supply Chain Management. The SAJIE topic spread leans towards Project Management and Production-oriented research in comparison with the relevant international trend. The proportion of South African IE publication outputs seem to be on a par with recent international trends in the subject areas of Information Systems and Technology, Operations Research, Supply Chain Management, and Total Quality Management.

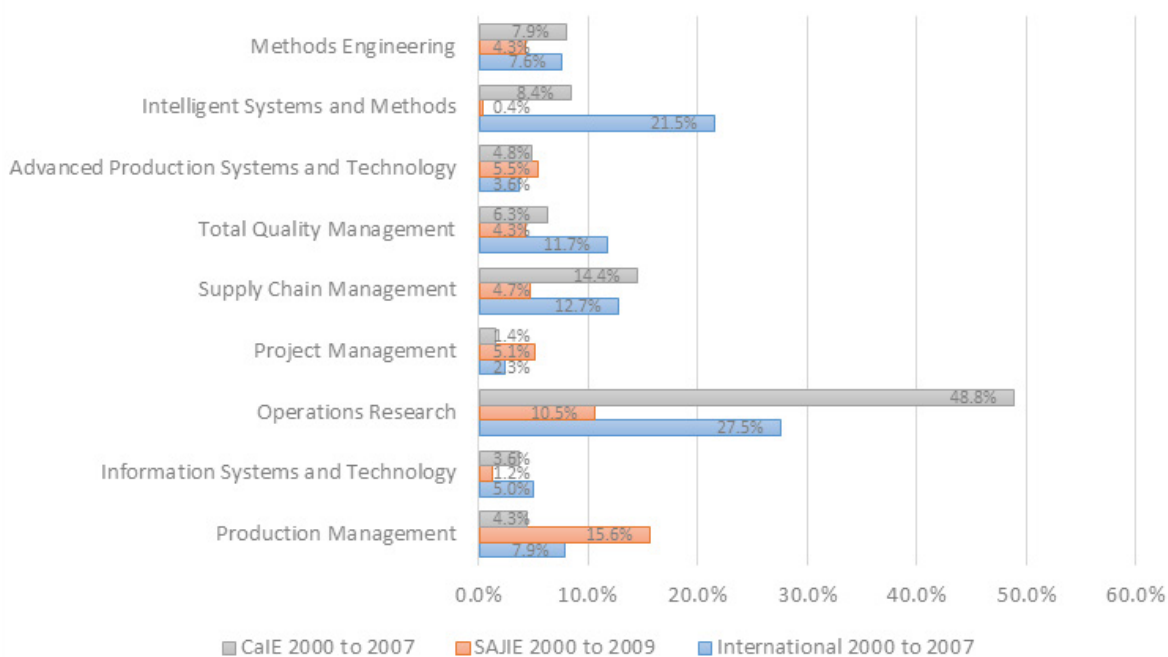


Figure 3: Proportion of research on different IE topics in SAJIE, CaIE and internationally – Source: Adapted from Uys et al. [9]

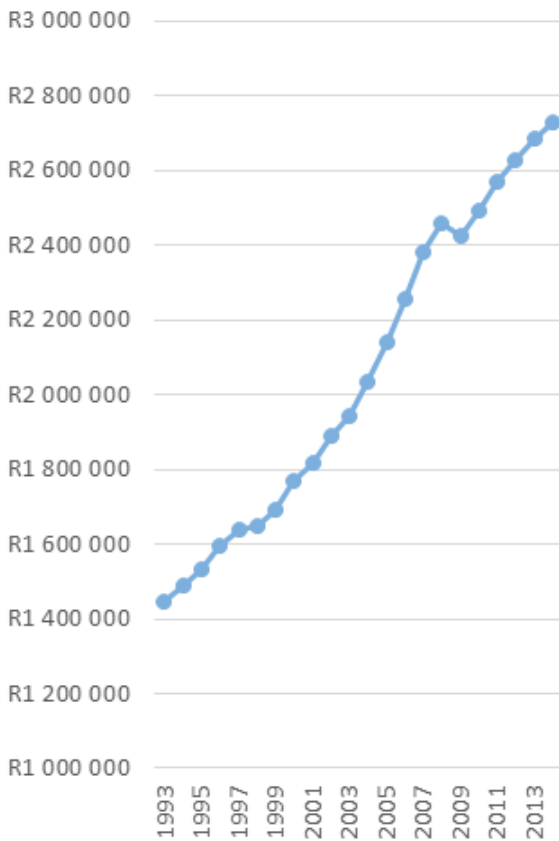


Figure 4: GDP at constant 2010 prices (R million) [10]

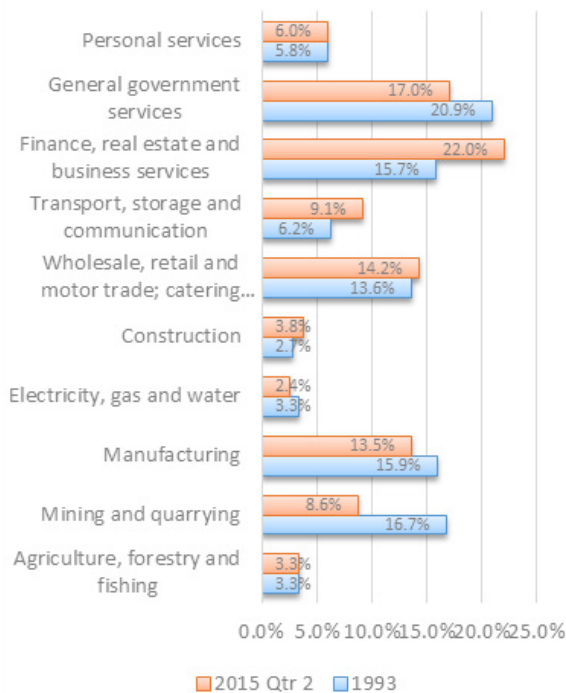


Figure 5: Percentage of GDP per industry – Source: 2015 Q2 vs 1993 [10]

South African Economic Development

The South African economy experienced significant growth during the past 20 years. Figure 4 shows the GDP at 2010 prices from 1993 to 2014, as published recently by Stats SA [10], which reflects an increase of 89% over the period.

But, as shown in Figure 5, the contribution to the GDP per industry sector has changed since 1993. Mining and manufacturing were significant activities in 1993, but these have decreased considerably up to the present time from 16,7% to 8,6% and 15,9% to 13,5%, respectively. The finance, real estate and business services industry has become the most dominant sector, surpassing government services, mining and manufacturing.

This means that IEs are now employed in a very different economy compared to 20 years ago, and as a consequence one can expect that the manner in which IEs are utilised has also changed.

South African Education System

In the 2012 Infrastructure Sector Research Survey carried out by executive search firm Landelahni Business Leaders Amrop SA, the engineering graduate skill shortage was highlighted [11]:

Of the 600 000 candidates who wrote school-leaving examinations in 2009, only 22% passed maths higher grade and only 7% passed physical science higher grade. In the same year, only 28% of students in public higher education institutions were enrolled for programmes in science, engineering and technology.

In addition, total graduations (degrees and diplomas) across all engineering disciplines between 1998 and 2010 numbered 70 475, at a 13,8% pass rate. Of this total, 29 280 engineers graduated with degrees from universities, which is an average of 2 252 per year. While there was an upward trend for black and female engineering graduates, the average university pass rate of all engineering students was 16%, far below the international average of 25% [11].

As part of a working group initiated by the Department of Higher Education and Training (DHET) in 2013 to determine the scarce skills for 18 strategic integrated projects (SIPs) in South Africa, an industrial engineering occupational team compiled a report. One of the key findings was that the supply of IE practitioners had not been able to match the significant demand-side growth in roles requiring IE skill sets, whether or not they were defined as such [12].

SOUTH AFRICAN INDUSTRIAL ENGINEERING APPLICATION STATUS

In South Africa, industrial and production engineers are recognised as No 8 on the scarce skill list of the DHET [13]. In order to address this scarcity, the nature and application of current industrial engineers in South Africa need to be understood. This section therefore analyses the following aspects:

- IE university studies and qualifications;
- IE employment in the industry sectors;
- IE race and gender profiles;
- IE utilisation and competence; and
- IE income profiles.

The following vehicles were used to gather data to reflect the status of industrial engineering in South Africa:

- An IE survey, constructed on SurveyMonkey [14], was distributed to SAIIE members, industrial engineering Facebook and LinkedIn groups, and industrial engineering alumni of the University of Pretoria, Stellenbosch University, Cape Peninsula University of Technology (CPUT) and Tshwane University of Technology (TUT). The number of responses received was 415. Because only a certain number of university alumni were targeted, the results of this survey should not be used to compare universities with each other.
- The presidential address at the SAIIE AGM of 2011 [15], and additional data analysis on the SAIIE member database containing 2 088 members, with the approval of the current SAIIE president.
- An internal SAIIE investigation into the requirements for BTech and NDip graduates in Industrial Engineering, performed by LHA Management Consultants in 2015 [16].

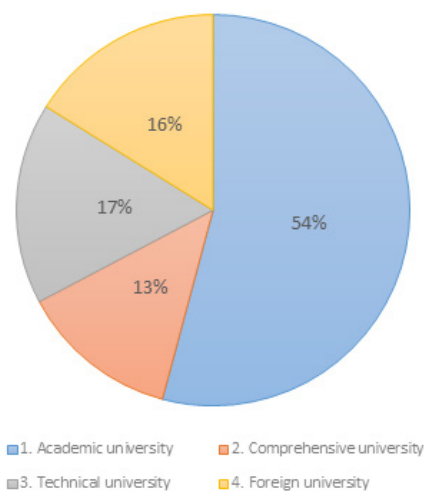


Figure 6: IE qualifications at university types for all ages – Source: SAIIE member data

- Ad hoc enquiries related to the racial composition of programmes at academic industrial engineering departments in South Africa.

IE University Studies and Qualifications

The institution where each IE received his or her highest qualification was analysed. Each university was categorised as one of the following:

- Academic university, sometimes termed traditional university (e.g. University of Pretoria, Stellenbosch University, North-West University Potchefstroom Campus);
- Comprehensive university (e.g. University of Johannesburg (UJ), Nelson Mandela Metropolitan University);
- Technical university (e.g. TUT, CPUT); or
- Foreign university (situated outside the borders of South Africa).

Since the comprehensive universities all deliver technical qualifications in industrial engineering, it makes sense, for the purposes of this analysis, to group comprehensive and technical universities together. Owing to the number of foreign universities appearing in the data sets, no attempt was made to categorise foreign universities as academic or technical.

It is important to note that the survey data are skewed towards those universities where the author had alumni access. The SAIIE member database is therefore more representative of the university profile. It was found that the majority of IEs were sourced from an academic university (see Figure 6), which was also true of the 20- to 29-year age group (not shown). The picture did not change when the focus was placed on older groups: a significant portion (24%) of IEs in the 40- to 49-year age group originated from foreign universities (see Figure 7).

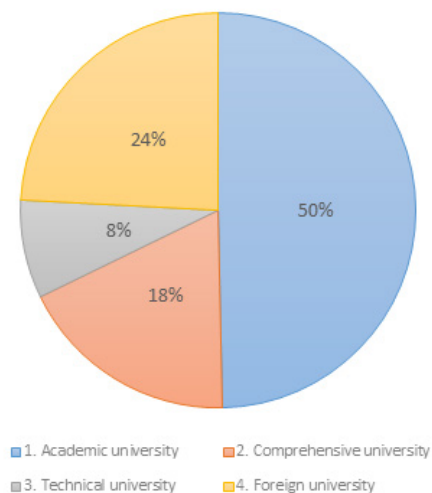


Figure 7: IE qualifications at university types in the 40 to 49 age group – Source: SAIIE member data

There is currently a trend where well-qualified and experienced mid-career IEs from neighbouring countries, such as Zimbabwe, immigrate to further their careers in South Africa.

When one examines the profile of highest qualifications in Figure 8, the results of University Type analysis in Figure 6 and Figure 7 is confirmed – the majority of IEs have academic qualifications. This graph also shows that 35.5% of IEs on the SAIIE member database have a postgraduate qualification (indicated in blue in Figure 8), and 4.2% have degrees on a doctoral level.

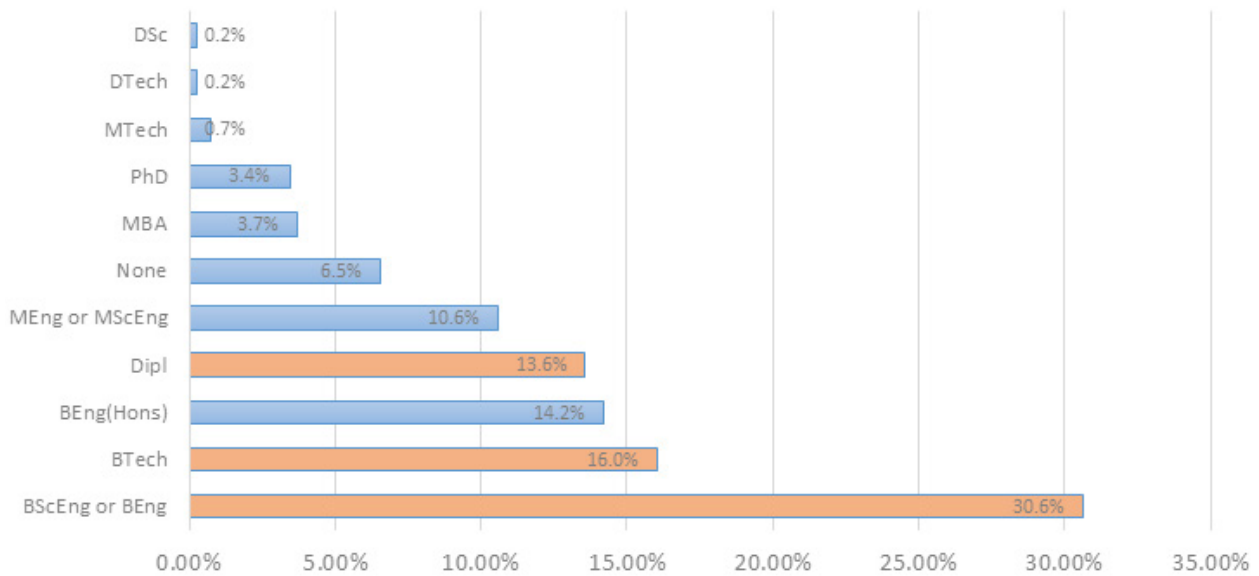


Figure 8: IE highest qualifications as a percentage of IE population – Source: SAIIE member data

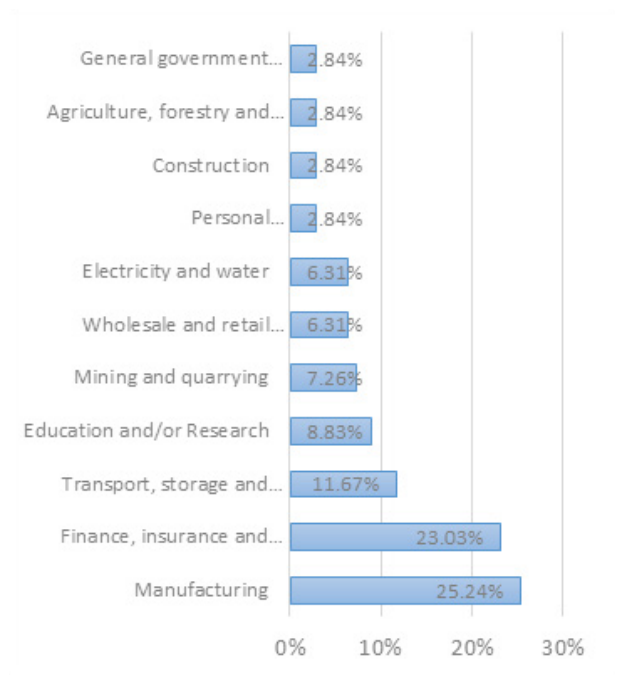


Figure 9: % of IEs employed per industry sector – Source: IE survey

IE Employment in the Industry Sectors

The employment aspects of all IEs on the SAIIE member database and the IE survey were analysed and categorised into industry sectors. A surprising aspect of the industry sector analysis was that the manufacturing sector is still the largest sector employing IEs (see Figure 9). This was confirmed by analysing the 13 largest employers in the SAIIE member data (see Figure 10).

A useful analysis was to compare the percentage of IEs in each industry sector with the size of the

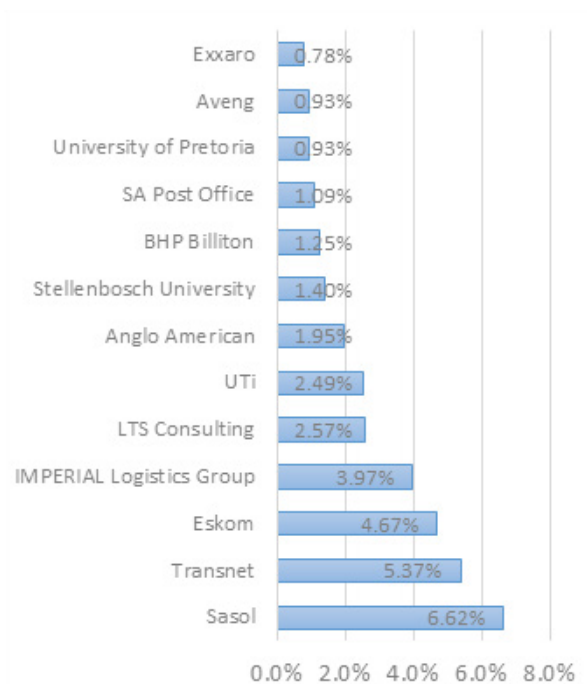


Figure 10: Thirteen largest IE employers as a percentage of members – Source: SAIIE member data and [15]

industry sector shown in Table 1. Another recent survey performed by LHA Management Consultants for SAIE confirmed that IEs were still mainly employed in ‘traditional’ sectors such as manufacturing (13,5% of GDP) and construction (< 4% of GDP), and fewer were employed in wholesale and retail trade (14,2% of GDP) [16]. General government services comprised 17% of the GDP, but less than 3% of industrial engineers work in this sector. This thus represents a significant opportunity for IEs, who can make a meaningful contribution in bringing efficiency to this sector that is often considered inefficient.

When one considers the number of IEs employed by the 13 largest employers, it is interesting to note that IEs are distributed over a large number of employers, and that employer no 13 already employs only about 10 IEs on the database sample. IEs therefore work in very small numbers in most organisations. This contributes to identity and possible career advancement issues, especially for the young inexperienced IE.

IE Race and Gender Profiles

Industrial engineering as a discipline is not isolated from the challenges posed by race and gender in the South African and global context.

Figure 11 shows that for all SAIE registered members, the white male group is still the largest group (44,3%). However, transformation has had a significant impact and the combined population of white female, Indian, coloured and black IEs now outnumber the white male population. Figure 12 shows the same data, but filtered for all IEs younger than 40. It is promising to be able to show that the black male population is well represented compared to its white counterparts (showing some success with transformation), but it still requires considerable intervention to be able to provide a representative picture of the racial composition in South Africa.

Table 1: South African industry as a percentage of GDP – 2015 Qtr 1 Source: Adapted from [10] and [16]

Sector	% of GDP	Growth trend (2005–2015)
Finance, insurance and business services	22,0%	Average
General government services	17,0%	High
Wholesale and retail trade and accommodation	14,2%	Average
Manufacturing	13,5%	Low -
Transport, storage and communication	9,1%	Average
Mining and quarrying	8,6%	High
Personal services, healthcare, etc.	6,0%	Low
Electricity and water	2,4%	High +
Construction	3,8%	High +
Agriculture, forestry and fishing	3,3%	Low

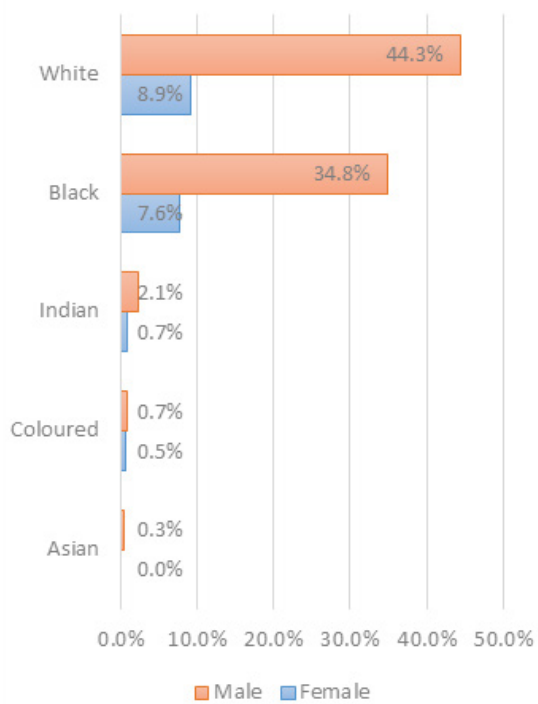


Figure 11: Race and gender over all ages – Source: SAIE member data

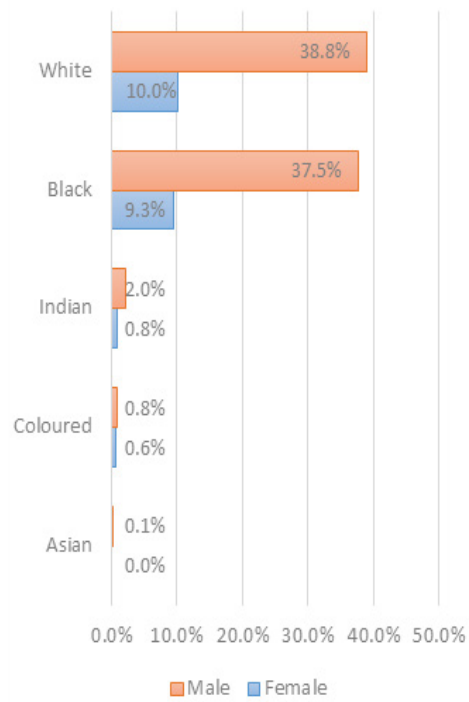


Figure 12: Race and gender younger than 40 years – Source: SAIE member data

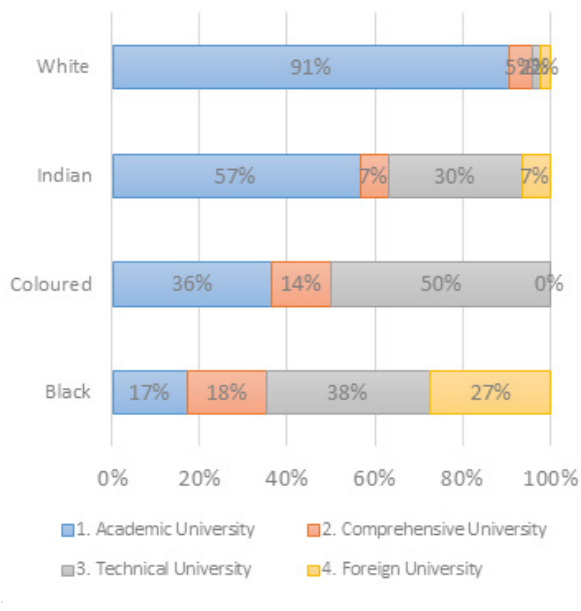


Figure 13: University type per race – Source: SAIE member data

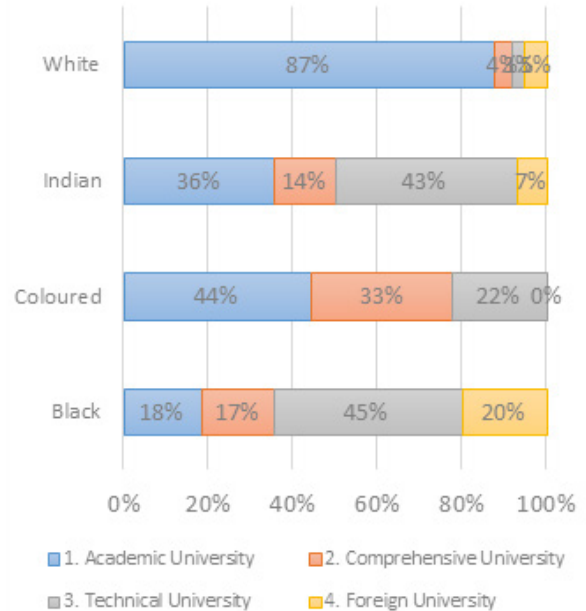


Figure 14: University type per race – Source: IE Survey

However, when the university type profile per race is examined, a worrying picture emerges which is confirmed by both data sets (SAIIE data and the IE survey data). Approximately 90% of white IEs have an academic qualification compared to less than 20% of black IEs. The sample size for the other race groups is very small, so the similarities between the data sets are less apparent. Similarly, a disproportionately small percentage of white students enrol for the technical qualifications (2% in technical universities, and 5% in comprehensive universities). The consequence is the following, as shown in Figure 15:

- Academic programmes are 83% white, and 17% black, coloured and Indian (BCI).
- Comprehensive university programmes are 75% BCI and 25% white.
- Technical university programmes are 95% BCI and only 5% white.
- Foreign university graduates are 90% BCI and 10% white.

The figures provide a clear picture of the disparity regarding race and education type, and filtering on a younger age bracket provides an even more discouraging picture.

In order to confirm and understand the racial profiles of the IE academic university students, additional information regarding the 2015 first and final year IE class compositions was requested from the academic programmes at Stellenbosch University (provided by the author), University of Pretoria [17], University of Witwatersrand [18], and North West University [19]. Since the data are of a sensitive nature, only a summarised version is given in Table 2. The table shows that the four industrial engineering academic programmes currently have only between 23 and 25% black, coloured and Indian (BCI) students. This is an improvement over the 17% BCI component with academic qualifications found in SAIIE member data.

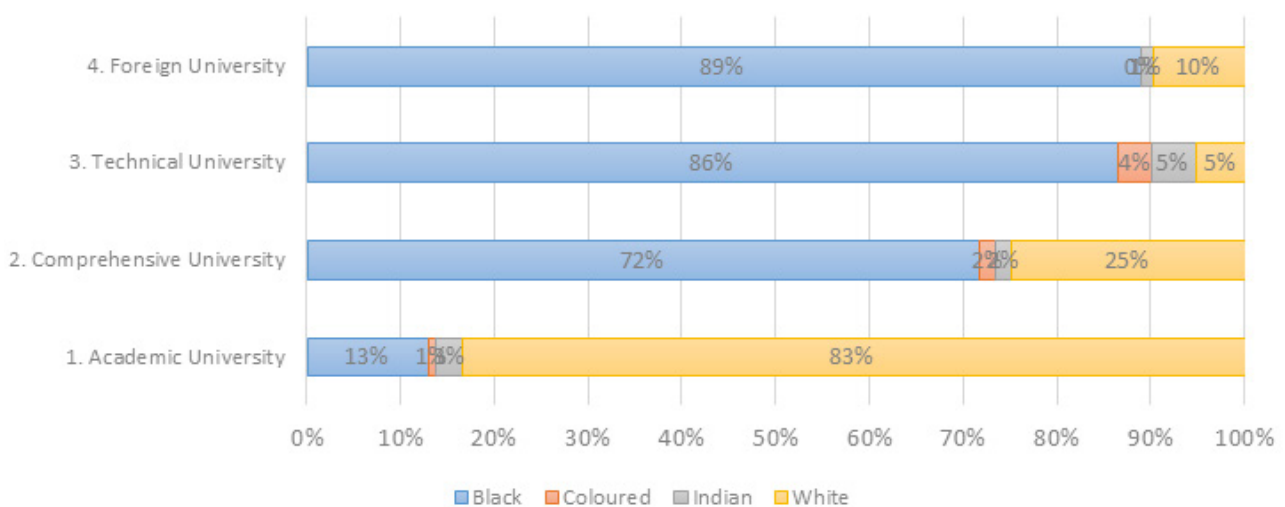


Figure 15: Race composition per university type – Source: SAIIE member data

Table 2: Race profile of first- and final-year students at IE departments at academic universities [17]-[19]

Year	White	Black	Coloured	Indian	Total	% BCI
1st & 4th	444	88	16	36	584	24%
1st year	282	62	6	18	368	23%
Final year	162	26	10	18	216	25%

The University of Pretoria (UP) has the most industrial engineering academic students with SU second when final year students are considered (see Figure 16 and Figure 17 for the distribution of all students in the academic programmes, irrespective of race).

Table 3 ranks the universities in terms of percentage of black, coloured and Indian (% BCI) students from lowest to highest. Furthermore, the admission policy is summarised and additional clarifying notes are provided. The University of Witwatersrand (Wits) has the IE programme with the smallest enrolment, but its racial composition reflects the South African demographics most closely. It is not clear whether the Wits admission policy makes it easier for students from previously disadvantaged backgrounds to gain admission, given the fact that there is not a subminimum requirement as for

the other universities. All the other universities, and especially North-West (NWU) and Stellenbosch, have a long way to go before their student racial compositions are representative. Both the University of Pretoria and Stellenbosch University have extended degree programmes, where students who are academically less advanced may follow a programme containing additional courses to strengthen students' academic foundations. Given that Pretoria and Stellenbosch currently have the largest IE student numbers and therefore the most capacity, the biggest impact on the racial composition – and therefore on transformation – in the Industrial Engineering Academic Programme can be realised if more BCI students can be encouraged to enrol in these programmes.

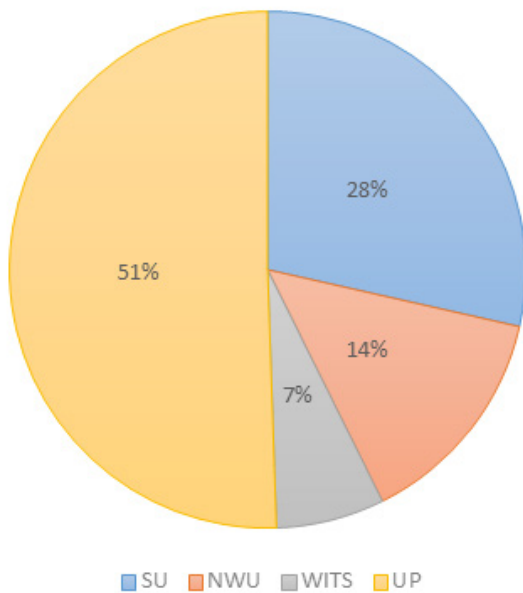


Figure 16: First-year student distribution in academic universities

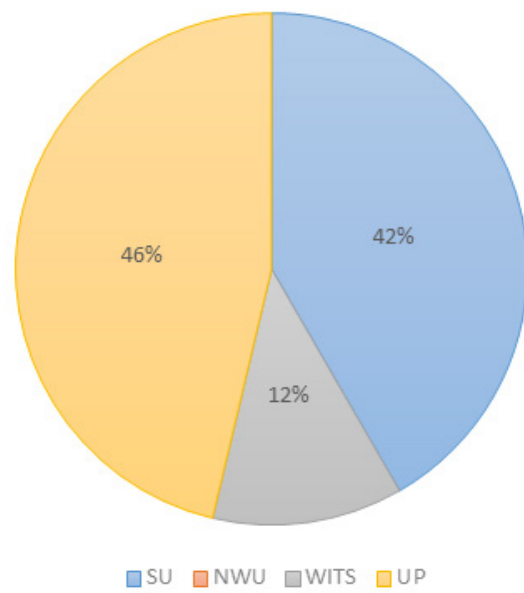


Figure 17: Final-year student distributions in academic universities

Table 3: Academic university IE Department ranked on % BCI, with Admission Policies and Explanatory Notes

Academic university	% BCI rank	Admission policy	Additional notes
North-West University (NWU)	4	Mathematics level 6 (70–79%) and Physical Sciences level 5 (60–69%); Afrikaans or English level 5 (60–69%) [20].	New programme, only first- year students' data available.
Stellenbosch University (SU)	3	>60% in Physics and >70% Mathematics. Admission score = Maths + Physical Science + 6 × avg. of matric excl. Life Orientation. Current target for 2016 is >620, but >600 is considered for BCI. Limited space per discipline [21].	The SU Engineering faculty has followed a fully bilingual route over the past two years, with parallel tracks (Afrikaans and English) for junior years and translation services for senior years. An extended degree programme is available for students from previously disadvantaged groups who do not meet the minimum requirements. IE lags behind other engineering disciplines at the university with respect to % BCI.
University of Pretoria (UP)	2	Admission point system (APS). Summary: If APS ≥ 36, and Afrikaans or English > 60, Maths > 80 or >70 if Physical Science >80, then allowed into 4-yr programme. If APS 30–36, Maths >70 and Physical Science > 60, then 4-yr programme possible with proficiency test, otherwise extended programme (Engage) If APS 25-30, Maths >60 and Physical Science >5, then Engage possible after proficiency test [22].	The UP engineering programme has been English-based for a number of years, and this has had a positive impact on making the programme more accessible.
University of Witwatersrand (Wits)	1	Admission point system (APS) where English First Language and Mathematics get a higher weight, and Life Orientation a lower weight. No minimum requirement in any subject, but APS < 36 not likely to be accepted [23].	% BCI is by far the highest, and the IE enrolment is representative of SA demographics. Wits is a predominantly English university, and had a more liberal approach during the apartheid years, which resulted in greater accessibility for other culture groups.

IE Utilisation and Competence

The survey collected data on the types of industrial engineering and engineering management activities in which respondents were involved in their current or previous employments, as well as their comfort in the area. The areas considered were:

- Project management;
- Productivity improvement;
- Work-study;
- Production engineering;
- Facility layout and material handling;
- Cost assessment and cost/benefit analysis;
- Information system & systems design;
- Operations research & simulation;
- Logistics;
- Quality assurance;
- Automation & robotics;
- Technology or engineering management; and
- General management.

This was then used to calculate a utility complexity factor. The utility complexity factor takes the complexity of an activity area (e.g. the application of operations research is generally more complex than work-study), as well as the experience and comfort factor into account, to calculate a score for each respondent. For example, if respondents reported that their responsibility included complex areas such as operations research, combined with feedback that they were comfortable in this area, the result would be a high score. Alternatively, if respondents had done work-study, and were less comfortable, this would result in a much lower score. While the mechanics of the utility factor has not

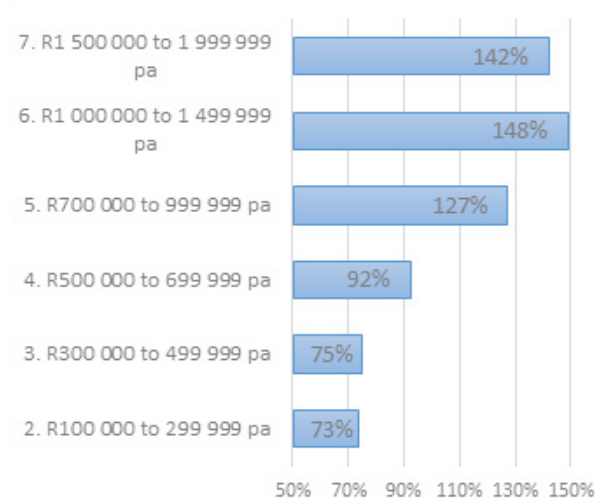


Figure 18: Utility complexity factor vs earnings – Source: IE Survey

been discussed in detail here, it is nevertheless useful for comparison purposes so as to measure whether respondents have been exposed and are suited for more complex tasks, or simpler tasks. As a check to confirm the validity of the factor, there should be a correlation between earnings and the utility complexity factor, and Figure 18 indeed shows a strong correlation (owing to small sample sizes, the < R100 000 and > R2 000 000 categories were removed).

Figure 19 shows that IEs with a technical university background have a lower utility complexity factor than IEs with an academic university background.

This is reflected and confirmed in the survey performed by LHA Management Consultants, which found that IEs with a BTech or NDip qualification had a more limited application in industry [16]:

- Figure 20 indicates that 50% of employers suggested that NDip skills were too low, and 33% suggested that BTech skills were too low.
- Figure 21 shows that the desire to appoint more graduates (that is academic university graduates) far exceeds the desire to employ more NDip or BTech engineers.

This thus not only divides the discipline, but also limits the transformation process within the IE discipline. It thus seems, from the figures above, that while industrial engineering is recognised as a scarce skill in South Africa [13], the scarce skill requirement is mostly for IEs from the academic universities. It seems that the higher education process is therefore not satisfying the demands of the country, in that the right mixture of IEs is not delivered to the market.

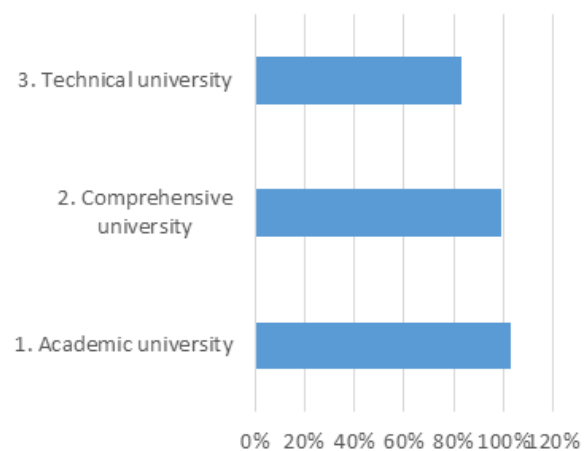


Figure 19: Average Utility complexity factor vs university type – Source: IE Survey

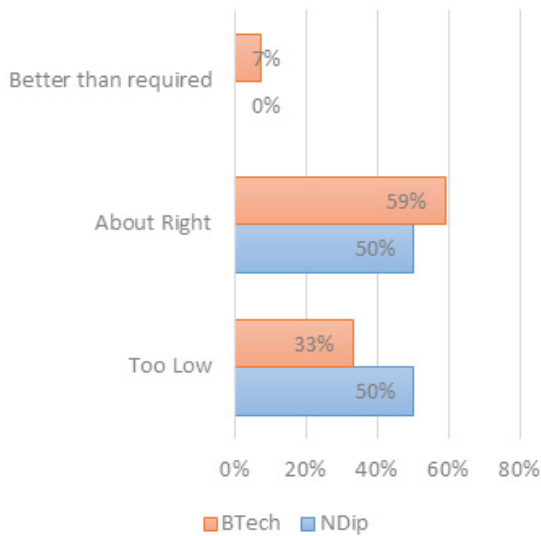


Figure 20: The level of competence and workplace-applicable skills of NDip/BTech graduates [16]

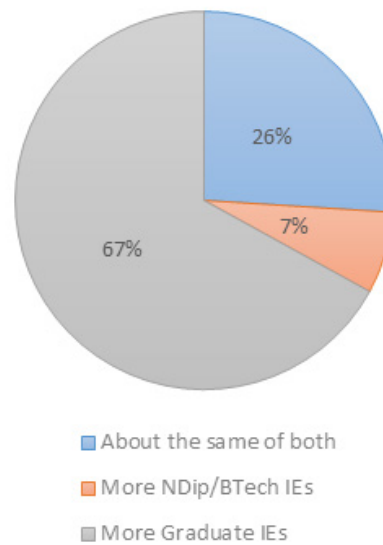


Figure 21: Employers' employment preference (NDip/BTech vs academic (graduate) engineers) [16]

IE Income Profiles

The survey captured the gross income of all participants, as shown in Figure 22. Figure 23 illustrates, as may be expected, that the number of years of experience has a strong correlation with income, but it is interesting to note that there are a number of younger IEs with less than 15 years of experience who are top earners in this analysis.

When income and gender are examined (Figure 24), it seems that female IEs have a similar income profile as the male IEs, but that males are still dominant in the top-earner categories.

When income and university type is examined (Figure 25), the more limited career growth of the technical and comprehensive university graduate is very apparent. Academic university graduates advance faster and earn significantly more in their careers.

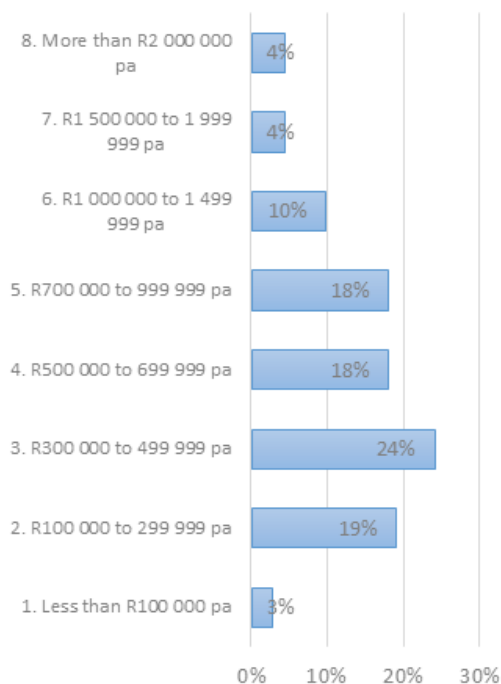


Figure 22: Gross income profile – Source: IE Survey

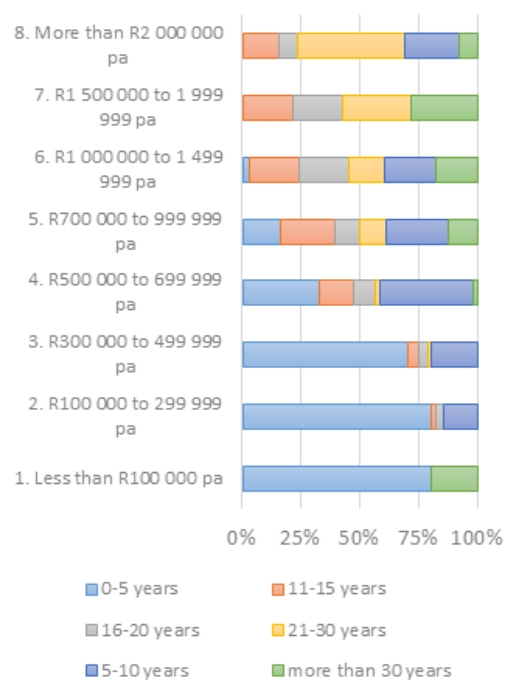


Figure 23: Gross income vs experience – Source: IE Survey



Figure 24: Gross income per sex – Source: IE Survey

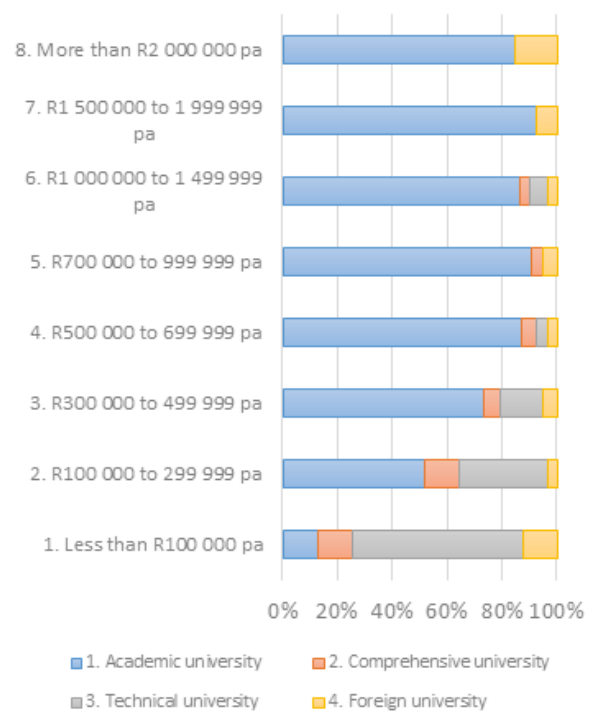


Figure 25: Gross income per university type – Source: IE Survey

DISCUSSION AND CONCLUSIONS

Industrial engineering in South Africa is a strong and established discipline which is correctly recognised as a scarce discipline.

The discipline in South Africa follows the international technology trends and the proportion of research fields of recent South African industrial engineering publication outputs seems to be comparable with international research trends.

Industrial engineers are involved in most of the industry sectors, but it is a clear that IEs are not proportionally active in the in the general government services sector. This sector thus represents an opportunity for industrial engineering. It must be noted, however, that this sector is more sensitive about the racial composition of its workforce, often sacrificing utility and efficiency for the sake of transformation (for an example of the engineering capability degradation of local governments, refer to [24]).

Academic university IE graduates seem to have a better utility and application in industry and therefore earn significantly more in their careers than university graduates with technical university qualifications (BTech and NDip). Technical university graduates have a more limited application and the industry is seeking more

academic graduated IEs, or alternatively to enhance the curriculum of the technical universities so as to deliver more suitable IEs to the industry.

Academic IE programmes do not deliver sufficient BCI IEs, and most academic programmes do not meet transformation expectations. Black IEs are mostly educated in technical and comprehensive universities, while white IEs are predominantly from academic universities.

The result is that BCI IEs end up in positions where they are less influential and earn less, and are therefore not clear enablers of the drive to attract more young people from disadvantaged backgrounds to become industrial engineers. This hampers the growth of the discipline in significant industry sectors such as the general government services sector, where the IE discipline needs to have more BCI IEs of the appropriate stature to grow in this sector.

The opportunities thus lie with:

- ensuring that there are more graduate BCI IEs graduating from academic programmes, who can then eventually be in a position to grow IE in the underrepresented industry sectors. This represents an opportunity for the academic programmes. Academic IE programmes need to

understand why they fail to attract sufficient BCI students of the required standard and need to find ways to encourage BCI students to enrol in the academic universities.

- developing and enhancing the curricula of the technical industrial engineering programmes to ensure the delivery of IEs to industry that address some of the shortcomings, and lower utility and application. Comprehensive and especially technical universities also need to understand why they no longer attract white students in representative numbers.
- sensitising and encouraging employers in the underrepresented industry sectors on the positive impact that IEs can have in their industries, and also equip young IEs to better suit these sectors.

- creating a working group within the industrial engineering community, consisting of representatives from all the industrial engineering programmes, the largest employers and SAIE council representatives, to share data and find solutions.
- identifying successful BCI role models, and use these role models to market industrial engineering in schools, so that stronger candidates from the BCI community are attracted.

This article is a first step in understanding these issues in the industrial engineering discipline. Future research is needed to understand the reasons why all the universities (academic and technical) are unable to attract student numbers in representative proportions, and what needs to be done to correct these imbalances.

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