

THE DEVELOPMENT OF THE INDUSTRIAL ENGINEERING PROFESSION IN SOUTH AFRICA⁽¹⁾

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One cannot develop an identity, a consciousness, an understanding or a philosophy without an historical awareness or background knowledge of the events and the people who contributed to a particular development. Background knowledge provides perspective on the progress made and of the accelerating rate at which changes are taking place. It must be viewed in the context of the thinking, attitudes, values, and culture at various stages in the past. Recording the past is also an acknowledgement of the contribution to the profession made by various groups and individuals. With this in mind, this article sets out a brief history of the evolution, role, and organisation of the South African industrial engineering profession.

South African industry progressed slowly before the discovery of diamonds and gold, as the main economic activities related to pastoral and agricultural pursuits. The mercantile system in use by the colonial powers did not favour local industrial progress, as it encouraged the importation of products and equipment into South Africa. The discovery of diamonds in the Cape Colony in 1867 and of gold on the Rand in 1886 led to the establishment of the mining industry in South Africa, and stimulated rapid economic progress, which in turn required that an infrastructure and facilities be built to accommodate the influx of people and their activities. These developments could not have taken place without importing the necessary management and engineering skills⁽²⁾. In a space of a few years the city of Johannesburg blossomed, and in 1892 the first train steamed into the city. In June of the same year a professional body of engineers - the South African Association of Engineers and Architects - was formed on the Rand with a membership of 43, and with civil engineer James Hennen Jennings⁽²⁾ as its first president. This was replaced by the South African Association of Engineers in 1902 and by the South African Institution of Engineers at the time of the Union of South Africa in 1910⁽³⁾⁽⁴⁾.

In an effort to regulate the engineering profession, the Legislative Council of the Transvaal Colony passed an amendment to an earlier 1903 ordinance when provision was made for "engineers' certificate of competency". It was later included in the Mines and Works Act of 1911⁽³⁾⁽⁴⁾. This certification is still in use today, and is complementary to engineering registration and legislation enacted towards the end of the 20th century.

In those early days of industrial development, the Cape Colony was an important maritime, assembly, and manufacturing region; and it was there that the first industrial organisation in South Africa was founded. "The South African Manufacturers' Association" was formed in Cape Town in the late 1890s. At the turn of the century almost half of all the goods produced in the four colonies were from the Cape⁽⁵⁾. By the time of Union in 1910, the share of manufacturing in the South African national income was 6.7 per cent. There were then only "2 473 industrial establishments employing 21 049 Europeans and 44 867 non-Europeans", a total of 65 918 employees. This figure seems small when compared with later giant industrial corporations; for example, in its 1995 Annual Report, ISCOR⁽⁶⁾ alone reported that it employed 48 131 people.

The skills and professional needs of the mining industry led to the establishment of educational institutions. The South African School of Mines was founded in Kimberley in 1896, but was moved to Johannesburg in 1908 and then to Pretoria as the Transvaal University College. These became the University of the Witwatersrand and the University of Pretoria in 1922 and 1930 respectively.

During the same developmental period of the South African economy, across the Atlantic, Frederick Winslow Taylor, a mechanical engineer, was studying, analysing, and

experimenting with the nature of work in the manufacturing industry. He introduced work process standardisation and best practice deployment in developing his scientific management principles and methods, and applied them successfully in industry to improve productivity and output. These studies and practices, together with contributions from others who followed, laid the groundwork of the field of industrial engineering. For many years, scientific management and manufacturing technology were seen as being part of the profession of mechanical engineering, until the increasing corpus of knowledge required the disciplines to be distinguished and separated.

The South African mining houses that grew with the economy subsequently diversified into finance, property, and other industries. The economic thinking at the time of Union was that the future of South Africa rested on agriculture and mining. The Cullinan Commission was established shortly after Union, and conducted the first inquiry into the establishment of industries. It reported that the best interests of South Africa would be served if adequate protection were given to agriculture and industry. Many of the recommendations were adopted in the Customs Tariff Act No. 26 of 1914, which was later recognised as one of the fundamental factors in the economic and industrial development of South Africa.

The early years after Union saw the development of many industries. By 1939, before the outbreak of World War II, there were 10 256 industrial establishments in South Africa - a four-fold increase in the thirty years since Union - contributing 17.6 per cent of the national income. Of particular importance was the establishment of the Electricity Supply Commission (ESCOM) and the Iron and Steel Corporation (ISCOR) in 1922 and 1928 respectively, by legislation.

Until 1939, much of the manufacturing industry was tailored for fabrication, jobbing, and batch production and industry had little experience with mass production. With the outbreak of World War II, imports were restricted, and industry was able to develop mass production techniques, high-precision engineering, and the managerial capabilities to supply munitions, equipment, and components vital to the war effort. "Wartime needs for steel and the local manufacture of numerous necessities brought about a sharp increase in demand which necessitated the expansion of the (ISCOR) company"⁽⁶⁾.

The increasing number of skilled people drawn to the developing manufacturing industry eventually created the need for a collective formal body representing what were then referred to as 'production engineers', a nomenclature later also entitled 'manufacturing engineers'. The South African Association of Production Engineers was formed in 1943 with Dirk Lion-Cachet as its first President. He remained in office until 1945, when he undertook a boat trip to Britain where he negotiated a link with the British-based Institution of Production Engineers (I.Prod.E.). The new body, formed in 1946, became known as the Institution of Production Engineers (South African Council). In those early years, membership numbered less than 50, even though the manufacturing industry employed some 360,000 people at the time. For many years, the Institution of Production Engineers (SA Council) provided a valuable service and represented the production engineering profession in South Africa⁽⁷⁾.

By the beginning of the 20th century, the USA had become the dominant industrial and economic power. One aspect that made a significant contribution to industrial development was the shift in emphasis towards the industrial processes through the application of innovative methods of management and production. What became known as the 'American system of manufacturing' involved, among other things, the use of interchangeable parts, new types of specialised machinery, and mechanisation. It enabled the training and employment of semi-skilled workers, as exemplified in Ford's assembly line. As a result, products could be produced more efficiently and competitively.

Economically, the main industrial concerns in the 19th century had been with managing what was then referred to as the 'factors of production': land, capital, and labour (in current terminology, these are resources or inputs to an industrial system). The emphasis

on these resources influenced the industrial economic thinking and the ideology of the time. There was the eventual realisation that it is the dynamic industrial processes that add utility and value to resources; and that appropriately engineered and managed industrial processes can add value by producing innovative quality products at lower cost, thereby enabling greater affordability to a wider market, and in turn creating the opportunity for competitive advantages. Ultimately, the availability of affordable goods and services in a society promotes economic activity and contributes to the creation of wealth. Integrated systems, methods, and techniques that add value, eliminate waste, and improve industrial productivity and output became the specialisation of industrial engineers. They eventually organised themselves into a formal body, the American Institute of Industrial Engineers, in 1948, based in Norcross, Georgia⁽⁸⁾.

The following excerpts from a 1939 publication⁽⁹⁾ by Dexter Kimball, a leading figure in industrial organisation at the time, capture the development and thinking of those formative years of industrial engineering:

“The manufacturing expert may be a good judge of the necessary factory tools and appliances, but he is, in most instances, poorly informed regarding the latest economies in power-plant construction or electric lighting and similar correlated problems that have become specialities. The location, construction, equipment, and operation of a large industrial plant may require the services of many specialized advisers, and the work of directing such experts is rapidly coming to be recognized as a business in itself and has been named Industrial Engineering.” (p.115)

“...the term Industrial Engineer is becoming synonymous with one skilled in factory design, organization, and operation, who endeavours to rest his conclusions, not on simple empirical information or judgement, but, as far as possible, upon basic proved facts.” (p.141)

“Several titles have been used to denote this new field. It was first called Scientific Management, but this name was perhaps, not well chosen and has created some antagonism to the use of these principles, partly because of a lack of knowledge of the basic facts, and partly because of a well-grounded fear that there is grave danger in extending, to the extreme, some of the methods advocated. At present there is a tendency to apply the name of Industrial Engineering to the more technical aspects of management and the name Administrative Engineering to what may be called the business side of management, in which the engineer has been found useful. Whatever name may be applied to this work, it is certain that the ‘scientific method’ of attacking the problems of organization and management is correct, and that it points out the method of intelligently directing the construction and arrangement of factory buildings, the character of methods and processes, the organization of departments, the elimination of wastes, and the increase of efficiency in all phases of industrial administration where data and experience are applicable.” (p.142)

In 1940, the Industrial Development Corporation of SA Limited (IDC) was established by Act of Parliament with the main object of promoting the establishment of industrial undertakings and the development of existing undertakings on sound business lines. The IDC assisted and pioneered many industries. Perhaps the most notable with which it was involved in the post-war period were SASOL, the oil-from-coal project; FOSKOR, which mines the phosphate deposits at Phalaborwa; and SAICCOR, the rayon pulp factory at Umkomaas⁽³⁾.

The 1950s and 1960s saw major strides in more complex technologies visible to, and affecting the lifestyle and culture of, the general public: from new vehicles and jet airliners to satellites, the space programme, new materials (particularly plastics), telecommunications, and - perhaps the most influential for engineers - small-scale computerisation. While technology and engineering were rising in social status, and their contribution to society and economic progress was being recognised, engineering was still

generally perceived as 'applied science' and the engineer as a hands-on individual. In practice, the title 'engineer' was loosely applied to almost anyone in industry. Engineering lacked a clear identity, professional status, unity of the various disciplines, and a philosophy. As a consequence, a movement evolved to rectify these shortcomings, and a technology and engineering philosophy developed, distinctively different from the philosophy of science. One early attempt at defining the distinction explains that "science is concerned with what is; engineering is concerned with how things ought to be", through the practice of designing, creating and constructing "...artefacts"⁽¹⁰⁾.

Although a step forwards in the general thinking, the engineering philosophy was unsatisfactory and was limited to physical 'artefacts'. This limited thinking would plague industrial engineering for many years in relation to conventional engineering disciplines. There was a reluctance to appreciate that, while the conventional engineering disciplines are concerned primarily with the design of the tangible 'artefact', industrial engineering is concerned with the design and integration of the often intangible industrial processes to achieve a result. Moreover, the end result or output of the processes can lead to an artefact or a service.

In 1966, the Straszacker Commission took a more pragmatic approach in defining the practice of engineering:

- (a) *Involves the use of brains (intellect), energy, materials, systems, money and labour in the conception, operation and maintenance of undertakings for the conservation and optimum utilization of natural resources, for the provision of the means of communication and transportation, as well as the actual production, of a great variety of things.*
- (b) *Bridges the gap between science and human needs, and*
- (c) *Requires the knowledge and skills of several different categories of workers: entrepreneurs, managers, professional engineers, technologists, technicians and manual workers artisans, operatives and labourers.*⁽³⁾

It is noteworthy that there is an acknowledgment and reference to 'systems', 'operation...of undertakings' and 'production'; and to 'services' such as 'communication and transportation'. It is also inclusive of the various levels of engineering skills necessary in industry.

The engineering movement subsequently led to the enactment of the Professional Engineers Act 81 of 1968, "to provide for the establishment of a South African Council for Professional Engineers, for the registration of engineers and engineers-in-training, and for other incidental matters". It reserved the title and work to be performed by professional engineers, and gave the Council the power to accredit engineering university courses. In effect, registration created a 'legal presumption of competence'⁽¹¹⁾ for professional engineers.

"20 June 1968 was a (date) of great import for the engineering profession because it signalled official recognition by the Government for engineering as a self-governing profession. The growing use of the instrument of delegated authority, which at the same time limits interference by the state in a specific area of public interest."⁽¹²⁾

A professional engineers' institute was defined in the Act as "any association of engineers established for the purpose of furthering the interests of the engineering profession and which has been recognized in terms of section 7(3)(a)". This section empowered the Minister to prescribe requirements with which an association had to comply in order to qualify for recognition as a professional engineers' institute. The then Minister of Trade and Industry subsequently prescribed that a professional engineers' institute should have a minimum of 100 members, and that two thirds of the total membership should consist of registered professional engineers.

Although South African industry was aware of the importance of manufacturing methods and systems, the focus was on the physical manufacture of artefacts. At best, method and time study specialists were employed by industry. Indeed, mature industries, such as the mining industry, continued to employ Work Study Officers until the 1990s. At the time, engineering courses included elements of manufacturing operations and systems, but their consideration was incidental to the conventional engineering disciplines. Few individuals had the awareness or foresight for the need, the potential role, and the contribution to industry of trained industrial engineers with a knowledge of both engineering and business principles and capable of engineering industrial undertakings. It was left to the academics to lead the way. A few of them took the initiative; and they continued to play a lifelong influential role in the education and development of the industrial engineering profession.

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. Encouraged by the Dean of the Engineering Faculty, Prof. C.A. du Toit, K. Adendorff⁽¹³⁾ was involved in the industrial engineering courses at the university from its inception until his passing in 2014. He made it his life's mission to develop and promote industrial engineering in South Africa. Because of his consistent contribution to the profession spanning a period of over 50 years, he is regarded as the 'father of industrial engineering in South Africa'. He left a strong legacy at the university, which to this day produces the greatest number of graduate industrial engineers in Africa.

At the University of the Witwatersrand, T. Duggan⁽¹⁴⁾ was involved in and promoted manufacturing technology and metrology for many years after joining the Department of Mechanical Engineering at the end of World War II. It took passion, perseverance, and influence to overcome resistance from the other engineering disciplines, and this led to the establishment of a chair in industrial engineering in 1969. The chair was enhanced in 1980 by a sponsorship from Barlow Limited (later renamed Barloworld). Graduate industrial engineers emerged from the University in the late 1970s, and the first Black African industrial engineer graduated in 1984. The year 1983 saw the founding of the Materials Handling and Warehousing Centre.

Led by R. Reinecke⁽¹⁵⁾, the University of Stellenbosch introduced graduate courses in industrial engineering and manufacturing technology in the late 1970s, followed by a Centre for Robotics in 1985. Other South African educational institutions, including technikons and universities of technology, followed the trend by offering full industrial engineering courses. By the mid-1980s industrial engineering was well-established in South African academia, although industry was slower in receiving this trend.

By 1970 South Africa's manufacturing industry employed over a million people. The growing industry, the increasing technological awareness, and the institutional developments emphasised the need for a wholly indigenous body. The South African Institute for Production Engineering (SAIPE) was formed in 1968. It maintained a close relationship with the British Institution of Production Engineers (I.Prod.E.) through an agreement concluded in 1971. From the outset, the SAIPE took over the local administration of the I.Prod.E. and supported its members in South Africa.

The members of the SAIPE were an eclectic lot with a varied technical background and with a common general interest in manufacturing. It did not meet the membership requirements of the 1968 engineering legislation; as a consequence production engineers could not achieve the desired recognition in terms of the Professional Engineers Act. At the same time, a threat developed when the Work Study Association expressed the desire to change its name to the Industrial Engineers Association, which would have led to a restricted understanding and a dilution of the industrial engineering profession. With the blessing and funds of the SAIPE, a committee was established to respond to these developments, and in a pre-emptive move, in 1976 a company was registered with the name 'South African Institute of Industrial Engineers' - an 'Association not for Gain' in terms of Section 21 of the

then new Companies Act - thereby reserving the name of an institute for industrial engineers. T. Duggan⁽¹⁴⁾ and J. Burdes⁽¹⁶⁾ attended to the registration of the company and were its designated directors.

The company, South African Institute of Industrial Engineers (SAIIE), existed only in name for the next five years, and was formally launched at the end of 1981 when it was felt that there were sufficient graduate industrial engineers to make it viable. The company directors, J. Burdes⁽¹⁶⁾ and T. Duggan⁽¹⁵⁾, were appointed acting President and Vice-President respectively. It is of interest that in those early days of the Institute, its council was wholly composed of electrical and mechanical engineering graduates, as were the majority of the founding members, who a few years later, numbered over 100. After a difficult start, the SAIIE was given impetus in 1984 when it was accepted as a recognised institute in terms of engineering legislation, and the industrial engineering profession was thus recognised in South African law as a separate branch of engineering. This was a timely development, as by then the manufacturing industry had grown to 200 000 enterprises employing 1.5 million people.

Despite these developments, the main challenges of the Institute at the time were finance, membership numbers, and awareness of the profession in South African industry. Many executives in industry had never heard of industrial engineering, and graduate industrial engineers were relatively scarce. P. Hatty⁽¹⁷⁾ promoted industrial engineering among fellow executives, and J. Bicheno⁽¹⁸⁾ produced a promotional video of best practices in three South African manufacturing companies (Toyota, Afrox, and GEC). In 1985 J. Bicheno⁽¹⁸⁾ and F. Sperotto⁽¹⁹⁾ established an active SAIIE Wits Centre, which collaborated with the South African Production and Inventory Control Society (SAPICS) in holding events; and in 1986 the Wits Centre organised the first industrial engineering conference in Africa, which has been held annually since then.

The South African Institute of Industrial Engineers (SAIIE), the South African Institute for Production Engineering (SAIPE), the Institution of Production Engineers (SA Council), the South African Production and Inventory Control Society (SAPICS), and the Operations Research Society of South Africa (ORSSA) existed side by side throughout the 1980s. The SAIIE and the SAIPE often cooperated in using the same facilities, in organising events, and in sharing the same journal, the *FWP Journal*. In 1986 the SAIPE adopted a new constitution and repositioned itself to serve the interests of technicians and technologists, as it was felt that graduate professional engineers were adequately served by the SAIIE. At the end of the decade, SAPICS also shifted its emphasis and promoted itself as a Society for Operations Management and later as a Society for Supply Chain Management.

P.S. Kruger⁽²⁰⁾ became the first graduate industrial engineer to be elected President of the SAIIE in 1986. He undertook the publication and production of the *South African Journal of Industrial Engineering* (SAJIE) and ensured its national accreditation. The first issue appeared in 1987. He remained the founding editor until 1996. R. Reinecke⁽¹⁵⁾ was interim editor in 1997 and 1998. S.J. Claasen⁽²¹⁾ took over the editorship from 1999 to 2007. Under his editorship the journal grew in stature and was internationally accredited and selected for coverage in the International Science Citation Index Expanded (SCIE), starting with Vol. 18(1) 2007. Claasen was followed by S. Adendorff⁽²²⁾ who further enhanced the journal and under whose editorship it became a fully on-line 'open access' journal. Today the Journal is a mature and established academic publication that attracts research papers from authors around the globe. C.S.L. Schutte⁽²³⁾ is the current editor.

Spurred by the affordability of computers and the example of Japanese industrial success, the 1980s saw the booming of industrial and management systems, practices, techniques, and technologies. These were accompanied by a confusing 'alphabet soup' of abbreviated names and acronyms. These subsequently took on a life of their own and evolved into specialised fields in industry such as Management Information Systems; Systems Engineering; Modeling and Simulation; Mechatronics and Automation; Robotics and Artificial Intelligence; Operations Research and Operations Management; Facilities Management and

Maintenance Systems; Quality Management Systems; Project Management; Logistics and Supply Chain Management... With these specialisations, formal knowledge communities and competing associations were formed, dispersing the potential membership of the SAIIE. The organisation of the workplace changed in just over a decade, which saw the information and knowledge worker gradually replacing the industrial worker; and the growth of the service industries, with industrial engineers increasingly being employed in the service industries. Indeed, today industrial engineers are active in a variety of industries: apart from traditional manufacturing, one finds them employed in industries such as healthcare, hospitality, finance, and throughout the supply chain.

On a broader front, these changes contributed to global trade and industry, to the increasing influence of corporates, to globalisation, to international economic interdependence, and to a new global economic order that challenged the established Bretton Woods economic system agreed by the leading nations after WWII. No longer was Africa seen as part of the 'Third World', but as one of the world's economic blocs with potential for trade and industry. The Southern African Development Community (SADC)⁽²⁴⁾ was established in August 1992, with the focus on the integration of economic development. The World Trade Organization (WTO) was launched in January 1995⁽²⁵⁾. And in South Africa, a new economic and political dispensation was achieved in 1994.

Rapid changes inevitably destabilise established institutions, and cause misunderstandings and stresses between conservative and progressive groups and individuals. While "...recognizing the disarray in the (South African) engineering profession..."⁽³⁾ "...it became increasingly evident that the other categories of persons in the engineering team, which were playing an extremely vital part in the practice of engineering, needed recognition"⁽¹²⁾. T. Duggan⁽¹⁴⁾ initiated and chaired the Interim Committee for the Registration of Engineering Technicians (ICRET) with the focus on promoting inclusivity and the registration of all levels of engineering practitioners. The Professional Engineers Act of 1968, which dealt only with matters pertaining to professional engineers, was then superseded by the Engineering Profession of South Africa Act 114 of 1990. The new Act aimed to regulate the whole engineering profession and to provide for the registration of professional engineers, technologists, technicians, and certificated engineers.

The tumultuous changes in the global and local industrial and professional environment during the previous decade meant that by the early 1990s the industrial engineering profession had lost clarity and context, and needed realignment. F. Sperotto⁽¹⁹⁾ undertook the project of redefining industrial engineering and of consolidating and reorganising the profession. He negotiated an agreement between the SAIPE and the SAIIE. Ultimately, at a general meeting in June 1994, the SAIPE and the SAIIE were dissolved and a new combined institute, the 'Southern African Institute for Industrial Engineering', was formed. In terms of the agreement it retained the abbreviated name, SAIIE, and the merged membership of the two institutes. The name of the new institute reflects the regional leadership, inclusivity, and aim of serving the interests of the profession as a whole. At the general meeting, R. Snaddon⁽²⁶⁾ was elected president of the new SAIIE. Industrial engineering was defined as "...the integration of resources and processes into cohesive strategies, structures and systems for the effective and efficient production of quality goods and services".

Subsequently F. Sperotto drafted the SAIIE Manual, which included the constitution, by-laws, and guidelines, and published a general history⁽²⁷⁾ commemorating the merger of the two institutes. The 1990s also saw the appearance of the first locally authored books relating to industrial engineering. R. Snaddon published *Starting Management Science*⁽²⁸⁾ in 1991; S. Adendorff⁽²⁹⁾ published *Operations Management*⁽²⁶⁾ in 1992; and in 1991, J. Bicheno started publishing a series of books on quality and lean systems and management⁽³⁰⁾.

Engineering legislation was again changed by the Engineering Profession Act (EPA), No. 46 of 2000. It consolidated the functions of the Engineering Council of South Africa (ECSA), a statutory body for the regulation of the engineering profession. The aim of the Act is "To provide for the establishment of a juristic person to be known as the Engineering Council of

South Africa; to provide for the registration of professionals, candidates and specified categories in the engineering profession; to provide for the regulation of the relationship between the Engineering Council of South Africa and the Council for the Built Environment; and to provide for matters connected therewith”⁽³¹⁾. ECSA’s core functions are the accreditation of engineering programmes, registrations of persons as professionals in specified categories (renewable every five years), and the regulation of the practice of registered persons. The Act also provides for recognition of voluntary associations every five years; the SAIE is currently recognised as a Category A Association.

In the past, engineering and manufacturing were primarily male-dominated professions, mainly for cultural reasons. Today, engineering, and particularly industrial engineering, includes many females in the profession⁽³⁶⁾, encouraged by pioneers such as Mary Parker Follett⁽³²⁾ and Lillian Gilbreth⁽³³⁾ and, in South Africa, S. Adendorff⁽²²⁾, who in 2000 became the first female in Africa to receive a Ph.D. in industrial engineering, and is co-author of the first South African textbook on operations management (1992). Indeed, today a large proportion of the industrial engineering students at universities are females. In the year 2000 M. Cilliers⁽³⁴⁾ became the first female president of the SAIE. Others followed soon thereafter. During this period, digital connectivity, accessibility, and knowledge transfer became prominent. The SAIE went online, a new corporate image with a modern logo for the new SAIE was introduced, and an important association with the Institute of Industrial Engineers in the USA was established⁽³⁵⁾.

Rapid changes in the social and industrial environment continue unabated, driven by accelerating technological developments, availability of information, networking, and globalisation. Developments in polymers and new materials from nanotechnology, for example; the variety of energy sources; new manufacturing processes and paradigms, such as additive manufacturing and distributed manufacturing; aerial and robotic networking; neuromorphic technology and predictive intelligence; the Internet of Things (IoT); the spread of integrating techniques, technologies and systems throughout the whole supply chain and its parallel, waste flow management; the increasing value-adding applications in the service industries; and the blossoming world of virtual reality; will extend the complexity of integrated systems and change the focus of industrial engineering, the needs of industry, the nature of work, the human-machine relationship, and the culture and lifestyle of people. Inevitably, the industrial engineering profession and its institutions will need to embrace these changes in order to remain relevant and to contribute meaningfully to industry and society.

- [1] Sperotto, F.: SAIE MANUAL, 1994. This article is an expanded version of the history section in the original 1994 SAIE Manual.
- [2] Key figures in engineering are set out in Bozzoli, G. R.: FORGING AHEAD - SOUTH AFRICA’S PIONEERING ENGINEERS, 1997, Witwatersrand University Press, Johannesburg.
- [3] Kros, Jack; Robinson L. R.: A CENTURY OF MECHANICAL ENGINEERING, 1993, South African Institution of Mechanical Engineers, Johannesburg.
- [4] Gericke, M.R.: History of Legislation for the Registration of Professional Engineers in the Republic of South Africa - Period 1890 to 1968, in ECSA , History section : https://www.ecsa.co.za/about/pdfs/Period_1890_to_1968.pdf
- [5] Bozzoli, B.: The Origins, Development and Ideology of Local Manufacturing in South Africa, *Journal of Southern African Studies*, April 1975, pp 195-214.
- [6] ISCOR (Iron & Steel Corporation), later to become part of ArcelorMittal South Africa. See <http://www.arcelormittalsa.com/Company/History.aspx>
- [7] Veit, Hans: President of the SAIE (1972-73); from an interview in 1993.
- [8] The American Institute of Industrial Engineers changed its name in 1981 to the Institute of Industrial Engineers (the same year as the SAIE started operating) to reflect the international membership base. <http://www.iienetz.org/>
- [9] Kimball, D.S. & Kimball, D.S. Jr.: PRINCIPLES OF INDUSTRIAL ORGANIZATION, 5th ed., 1939, McGraw-Hill.
- [10] Stanford Encyclopedia of Philosophy, section on ‘Philosophy of Technology’, 2013 www.plato.stanford.edu/entries/technology/
http://en.wikipedia.org/wiki/Philosophy_of_engineering
- [11] With registration, an engineer is presumed to be professionally competent in terms of the law. For general notes on legal presumptions in the law of evidence, see for example:

- Schwikkard P.J. & Van der Merwe S.E.: PRINCIPLES OF EVIDENCE, 3rd ed, 2010, Juta & Co.; and Botha, C.J.: STATUTORY INTERPRETATION, 5th ed., 2012, Juta & Co.
- [12] Gericke, M.R.: The History of the South African Council of Professional Engineers 1968-1991, in ECSA, History section https://www.ecsa.co.za/about/pdfs/Period_1968_to_1991.pdf
- [13] Adendorff, K. (1931-2014): Professor Emeritus of Industrial & Systems Engineering, University of Pretoria; President SAIPE (1981-2); President SAIIE (1984-5); President new SAIIE (1998-9); Honorary Fellow (1988); from an interview in 2014. See obituary in SAJIE Vol. 25 No. 3 and article by S. Claasen : Fifty Years in Industrial Engineering - Prof Kris Adendorff in SAJIE Vol. 23 No 2.
- [14] Duggan, T. O'D.: Associate Professor of Mechanical Engineering, University of the Witwatersrand; President SAIPE (1975-6); President SAIIE (1983-4); SAIIE Honorary Fellow (1986); from an interview in 2014.
- [15] Reinecke, R.: Professor Emeritus of Industrial and Manufacturing Engineering, University of Stellenbosch; President SAIIE (1986-7); Editor *South African Journal of Industrial Engineering* (1997-8); Honorary Fellow SAIIE (1995).
- [16] Burdes, J.P.: President SAIPE (1974-5); President SAIIE (1982-3; 1988-9), Honorary Fellow (1991).
- [17] Hatty, P. R.: President SAIPE (1976-7); President SAIIE (1985-6; 1987-8), Honorary Fellow (1994).
- [18] Bicheno, J.: Associate Professor of Industrial Engineering, University of the Witwatersrand. Later at the University of Buckingham and Cardiff Business School. Author of various books on quality, lean management, and manufacturing and service operations.
- [19] Sperotto, F.: President SAIPE (1986-7); President SAIIE (1989-90); President new SAIIE (1996-8); SAIIE Honorary fellow (2002).
- [20] Kruger, P. S.: Professor of Industrial & Systems Engineering, University of Pretoria; President SAIIE (1992-3); Honorary Fellow (2005); Founding Editor, the *South African Journal of Industrial Engineering* (SAJIE); for the foundation history of the SAJIE, see *South African Journal of Industrial Engineering* Vol. 23 No. 1.
- [21] Claasen, S.: Professor of Industrial & Systems Engineering, University of Pretoria; President SAIIE (1993-4). Editor, *South African Journal of Industrial Engineering* (1999 to 2007).
- [22] Adendorff, S.: Professor & Director of Facilities Management , University of Pretoria; Editor, *South African Journal of Industrial Engineering* (2008 to 2013); author of management books.
- [23] Schutte, C.L.S.: Professor of Industrial Engineering, University of Stellenbosch; President SAIIE (2009-2011); Editor of the South African journal of Industrial Engineering from 2013
- [24] SADC is currently composed of 15 member states, and is the main export market for South Africa with 14 per cent of its total trade in 2013.
See www.sadc.int/about-sadc/overview/history-and-treaty/
- [25] The WTO deals with the rules of trade between nations in order to assist producers of goods and services, exporters, and importers to conduct their business. See www.wto.org
- [26] Snaddon, D. R.: Barloworld Professor of Industrial Engineering, University of the Witwatersrand; President SAIIE (1994-5); later Professor and Director of the Department of Mechanical Engineering, Polytechnic of Namibia, Windhoek and responsible for the design and implementation of industrial engineering at the Polytechnic.
- [27] Sperotto, F.: IN THE FOOTSTEPS OF HOMO INDUSTRIALIS - A Chronology of Industry & Industrial Engineering, 1994, PICSIE Press, Johannesburg.
- [28] Snaddon, D.R.: STARTING MANAGEMENT SCIENCE, 1991, Juta & Co.
- [29] Adendorff, S.: OPERATIONS MANAGEMENT, 1992, Juta & Co.; a 2nd edition was published in 1999.
- [30] See, for example, the current editions of:
Bicheno, J. & Catherwood, P.: SIX SIGMA AND THE QUALITY TOOLBOX, 6th ed., 2005, PICSIE Books, Buckingham;
Bicheno, J. & Holweg, M.: THE LEAN TOOLBOX - The essential guide to lean transformation, 4th ed., 2009, PICSIE Books, Buckingham;
Bicheno, J.: THE SERVICE SYSTEMS TOOLBOX - Integrating lean thinking, systems thinking, and design thinking, 2nd ed., 2012, PICSIE Books, Buckingham.
- [31] Engineering Profession Act (46 of 2000), Preamble: https://www.ecsa.co.za/regulation/RegulationDocs/EngProfAct46_2000.pdf
- [32] Mary Parker Follett (1868-1933) is regarded as the first female pioneer of modern management, and was influential in the fields of organisational development and human relations.
- [33] Lillian Evelyn Moller Gilbreth (1878-1972) is considered to be the first industrial and organisational psychologist. Together with her husband Frank Bunker Gilbreth, they contributed to the field of industrial engineering. The book *Cheaper by the dozen* is a narrative of their structured and organised lifestyle.
- [34] Cilliers, M.: SAIIE President (2000-2002).
- [35] "The Southern African Institute for Industrial Engineering and IIE have established a partnership. The focus is on establishing a strong relationship for future initiatives, sharing of knowledge and resources, and building the industrial engineering profession globally."
<http://www.iienet2.org/Details.aspx?id=638>
- [36] See further, Nel H. : LEADERSHIP AND AGENCY BY WOMEN ENGINEERS IN SOUTH AFRICA, 2015, Partridge Publishing Africa. The author is a Past-President of the SAIIE (2009-2010)