Strategies to address the skills shortage in the delivery and maintenance of infrastructure in South Africa: **a civil engineering perspective**

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INTRODUCTION

The engineering profession plays a critical role in the delivery and maintenance of infrastructure. It is involved in:

- the detailed planning, design, construction and optimisation or condition assessment of infrastructure
- the development of short-, medium- and long-term infrastructure plans at both a portfolio and project level, and the administration of works contracts for the acquisition, refurbishment, rehabilitation and maintenance of infrastructure
- the strategic planning and management of the operation and maintenance of infrastructure, and
- specific duties relating to health, safety and environmental aspects of infrastructure as provided for in legislation.

The civil engineering discipline currently accounts for just less than half the number of professional engineers and professional engineering technologists registered with the Engineering Council of South Africa (ECSA). A major portion of the work undertaken by civil engineers involves public infrastructure.

The perceived shortage of engineers in South Africa has been a topic of conversation as far back as 1971 when the South

Table 1 Interventions recommended by Lawless in 2005

Time frame	Intervention
Short-term	▪ Retain senior professionals and appoint retired professionals to supervise and train young graduates and initiate and manage projects ▪ Review conditions of employment including remuneration, qualifications, grading, responsibility, authority and employment equity targets ▪ Attract people back into the industry ▪ Re-introduce structured workplace training through the industry
Medium-term	▪ Increase the number of technologists ▪ Improve the employability of national diploma graduates ▪ Implement comprehensive succession planning and associated training
Long-term	▪ Increase the number of graduate civil engineers

African Human Sciences Research Council (HSRC) released a report on the topic (Terblanche 1971). This report found that an annual average of 940 engineers (persons who possessed the qualifications to work as engineers, i.e. degree, corporate membership, government certificate of competency or equivalent qualification) in all disciplines, approximately 520 of which were in the civil engineering branch, would have to be added to the existing engineering corps during the period 1968 to 1973 in order to meet the demand for 14 585 engineers in 1973. The report also suggested that the projected demand for engineers in 1980 of 17 800 could be satisfied provided that:

1) *an average of 540 engineers per annum complete their studies at university over the period from 1968 – 1980, which amounts to a growth from approximately 420 in 1967 to 640 in 1980*

2) *an average of approximately 100 persons per year enter the engineering profession without an engineering degree*

3) *immigration provides a net gain of approximately 210 engineers per year (1968 – 1980), and*

4) *the growth in the country's economy is not more than predicted by the Department of Planning.*

The South African Institution of Civil Engineering (SAICE) published a book which examined the imbalances within the civil engineering profession in 2005 (Lawless 2005). This publication concluded that there is a "*critical shortage of experienced civil engineering professionals, particularly mid-career civil engineers responsible for production works*". This book suggested that, in order to meet demand in civil engineering, 285 engineers and 374 technicians should be graduated annually. Lawless recommended the short-, medium- and long-term interventions as stated in Table 1 to address the shortfall.

ECSA in its first newsletter, which was published in 2010, quoted its President as saying that "*currently South Africa has one engineer for every 3 100 people compared with Germany with one engineer for every 200 people. In countries like Japan, UK and USA, this ratio stands at about 1:310. Therefore South Africa needs to produce 10 times more engineers in order to compete favourably.*" (ECSA 2010a)

Consulting Engineers South Africa (CESA), which currently has more than 480 member firms, employing more than 22 000 people and earning 87% of their fees in South Africa, publishes a *Biannual Economic and Capacity Survey* that provides information on a number of indicators, including those relating to industry's capacity and the demand for staff. Their latest report (July to September 2011) indicates that the industry capacity utilisations of existing technical staff was approximately 90% during 2004 and 2005, peaked at 100% during 2007, dropped to about 80% during 2010 and is currently around 90% at a time when government is known to be under-spending on its budgets. This report also indicates that the number of firms wanting to increase staff fluctuates and is different for different categories of technical staff, as indicated in Table 2.

The Chief Executive Officer of SAICE has very recently confirmed that "*the heads of civil engineering departments from four local universities of technology all say their students are unable* *to secure sustainable work for in-service training, as well as post-graduation employment*" (Venter 2012). Lawless (2011) reported that between 45% and 99% of students at eleven higher learning institutions were unable to graduate due to no or insufficient experiential training.

The time has come to review some of the thinking around the shortage of civil engineering skills in South Africa and the strategies to overcome such shortages.

A CRITICAL REVIEW OF THE PERCEIVED SHORTAGE OF ENGINEERS IN SOUTH AFRICA

The population to engineer indicator

Lawless (2005) tabulated the numbers of registered engineers in various countries, based on an extensive desktop survey and the contacting of various institutions and registering bodies that provided data of varying reliability, detail and dates for data sets (see Table 3). Lawless did caution that some registration bodies similar to ECSA provided figures for professional engineers only whilst others provided figures for all engineers, whether registered or not. In particular, she singled out China and India as possibly representing all engineers and not just registered engineers. Lawless nevertheless used these figures to calculate population per engineer and, where data was available, provided comparative figures for population per doctor (see Table 3.)

Lawless, in interpreting her indicator "population per engineer", made the observation that "*although South Africa is perceived to be technologically stronger than many countries it is disconcerting that South Africa's ratio of population to engineer is not significantly better than Zimbabwe, Namibia and Tanzania and other less developed countries.*"

Extracts from Lawless's tabulation of population per engineer and population per doctor have been analysed and reported on in several reports, papers and publications. For example, the Engineering Professions Association of Namibia (EPAN) notified its members that "*this shows clearly that the number of our engineers is not enough for the population quoted*" (EPAN 2005). Nxumalo and Nordengen (2010) stated that "*Our ratio of engineers to population is a major challenge as we are behind even developing countries like India ....the ratio of population to engineers is significantly lower than various other countries. A comparison with other developing and developed countries suggests that South Africa is far behind. Western Europe and North America have an average of between 150 and 300 people per engineer. It is discomforting to note that both China and India are also in that company. South Africa has only one tenth of the engineers of those nations; therefore our needs are far greater than we can imagine.*"

ECSA has asserted that "*the international benchmark of an average population per engineer shows that South Africa lags behind other developing countries. In South Africa, one engineer services 3 166, compared to Brazil's 227 and Malaysia's 543 per engineer. The discrepancy in the benchmark points to one thing: South Africa is severely under-engineered.*" (ECSA 2010b)

It is easy to understand the indicator "population per doctor", as it is driven by the health of the people (disease burden, age profile, etc) and the funding / affordability of the available health care system. The distinction between doctors and other members of the health care team is well understood, as well as the patient–doctor relationship. This is not the case when considering the indicator "population per engineer", for the following reasons:

1) Registration can mean one of two things in different jurisdictions – recognition of demonstrated achievement of a defined standard of competency or a licence to practise. Accordingly registration can be voluntary or mandatory. As a result, the incentive or requirement to register varies (UNESCO 2010).
2) The registration culture varies from country to country. Some countries register three tracks equating to ECSA's categories of engineer, technologist and technician (UNESCO 2010). In some countries only the engineer, or the engineer and technologist, tracks are registered. The equivalency of the different tracks in different jurisdictions is not clear.
3) There is an inconsistent reporting of engineering graduation data. According to Duke University (2005), articles have typically "*stated that in 2004 the United States graduated roughly 70,000 undergraduate engineers, while China graduated 600,000 and India 350,000. Our study has determined that these are inappropriate comparisons. These massive numbers of Indian and Chinese engineering graduates include not only four-year degrees, but also three-year training programs and diploma holders.*"

An alternative indicator

Engineering works (e.g. civil and structural works, building services, works for the harnessing of energy, the treatment of substances, mining operations, transportation and mechanical and electrical power, and electronic and process systems) is driven by finance and not numbers of people alone. No matter how many people live in a geographical area, finance is required to undertake engineering works. A more understandable or rational metric is accordingly "GDP to engineer", as indicated in Table 3. The data in Table 3 paints a very different picture. Although South Africa has a population to engineer ratio of 3166:1 compared to a developed country average of 295:1, it has

Table 2 Percentage of firms wanting to increase staff but struggling to find suitable candidates (CESA 2012)

	Engineer	Technologist	Technician	Other Technical Staff	Support Staff
December 2007	94.5	90.6	89.4	52.1	28.7
June 2008	67.4	67.1	43.0	40.6	18.5
December 2008	33.2	11.3	9.3	2.5	2.3
June 2009	26.4	12.8	12.5	3.8	1.9
December 2009	26.1	73.6	25.5	14.9	14.0
June 2010	16.6	11.9	1.7	11.9	0.4
December 2010	81.5	18.3	18.3	10.1	5.8
June 2011	66.0	51.8	52.8	8.3	6.6
December 2011	74.0	36.0	22.0	4.8	6.9

a GDP to engineer ratio of US$16.4m:1 compared to US$11.5m:1 for developed countries. Accordingly, the shortage of engineers, based on the ratio GDP to engineer, suggests an order of magnitude lower shortfall, which aligns with other indicators such as those produced by CESA and current anecdotal observations.

What is immediately apparent in Table 3 is the variability of the data. For example, the ratio GDP to engineer in developed countries ranges from US$5.1 to 16.2 m per engineer, possibly due to inconsistencies in the reporting of the number of engineers. According to a recent UNESCO Report (2010), the lack of a clear-cut definition as to "*what is covered under the concept of engineering*" and "*who in the workforce is really an engineer*" has frustrated international comparisons. A better benchmark is to perhaps compare South Africa against the average for the English-speaking developed countries who are signatories to the Engineers Mobility Forum, i.e. Australia, Canada, Ireland, UK and the USA, who have an average GDP to engineer ratio of US$14.0m:1 and an average population to engineer ratio of 348:1. South Africa's GDP-based statistic of US$16.4m:1 is not more than 20% higher than this average, whereas the population-based statistic of 3 166:1 is 9.1 times higher.

The anomaly in the two statistics is in part explained by the findings of Hall, a scenario planner who studied commercial activities in South Africa many years ago. According to Lawless (2005), Hall concluded that the "*numbers employed to serve the white population matched those of the Western World, hence the impressive first world infrastructure serving mainly the white*

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South Africa's per capita income in 2005 was US$5192 whereas the comparative figure for Australia, Canada, Ireland, UK and USA was US$40282, i.e. 7.8 times higher. This figure is a similar order of magnitude to the difference in the population to engineer ratio of 9.1, being only 17% lower. Accordingly, the population to engineer ratio alone yields misleading and grossly exaggerated conclusions, as it ignores per capita income, which is a measure of the money available in the private and public sector to support engineering works.

Any comparison between countries based on GDP per engineer also needs to be viewed with caution. Apart from the aforementioned anomalies in the reporting on the number of engineers, what makes up the economy and the demand for infrastructure also need to be considered, as well as what types of engineers are required, e.g. discipline (civil, electronic,

Table 3 Population per engineer and GDP per engineer in various countries

Country	Population	Number of registered engineers	Population per engineer	Population per doctor	GDP per capita (IBRD World Bank 2008)		GDP per engineer (US$ million)
					rank	US$	
Western Europe							
Denmark*	5 520 295	30 926	179	273	16	47 793	8.6
Finland*	5 357 934	39 537	136	304	22	37 262	5.1
France*	60 656 178	220 000	276	297	24	34 008	9.4
Germany*	82 443 000	380 000	217	291	21	33 849	7.3
Greece*	15 000 000	87 337	172	199	29	22 285	3.8
Iceland	270 603	1 019	266	283	11	54 975	14.6
Ireland*	3 917 203	14 000	280	362	8	48 405	13.6
Norway*	4 600 246	37 685	122	308	3	65 267	8.0
Sweden*	9 254 613	44 352	209	291	19	39 621	8.3
UK*	58 821 000	189 406	311	492	20	37 266	11.6
Eastern Europe							
Hungary	10 661 747	4 815	2 214	437	40	10 962	24.3
Romania	23 434 194	8 056	2 909	523	60	4 575	13.3
North America							
Canada*	30 337 000	169 512	179	475	13	35 133	6.3
USA*	296 771 226	762 000	389	361	6	41 674	16.2
South America							
Argentina	36 260 130	80 000	453	354	55	4 836	2.2
Brazil	184 203 744	811 483	227	379	65	4 791	1.1
Chile	14 973 843	22 000	681	2 025	48	7 305	5.0
Australia							
Australia*	20 372 452	44 767	455	414	17	34 774	15.8
Asia							
China	1 300 000 000	10 000 000	130	593	86	1 721	0.2
Hong Kong	5 000 000	10 798	463	617	10	26 094	12.1
India	1 020 000 000	6 500 000	157	2 320	108	707	0.1
Japan*	121 000 000	400 000	303	476	23	35 604	10.8
Korea	45 985 289	21 534	2 135	585	34	16 441	35.1
Malaysia	25 500 000	47 000	543	1 436	53	5 250	2.9
Singapore	4 240 000	3 161	1 341	318	7	26 879	36.0
Sri Lanka	18 732 255	3 348	5 595	-	97	1 218	4.1
Africa							
Ghana	21 029 853	1 644	12 792	2 500	125	502	6.4
Namibia	2 030 692	320	6 346	4 545	82	3 049	19.3
South Africa	**46 888 200**	**14 806**	**3 166**	**1 493**	**67**	**5 192**	**16.4**
Swaziland	979 000	80	12 238	9 100	83	2 270	27.8
Tanzania	36 766 356	6 200	5 930	-	131	360	2.1
Zambia	11 261 795	881	12 783	11 100	126	636	8.1

* Developed country according to the UN's Trade and Development Index

mechanical, etc) and specialisations within a discipline (maintenance, construction, design, etc).

Irrespective of the projections for numbers of engineers based on the various indicators, an increase in the number of engineers will be required in South Africa to:

- address various aspects of sustainable development, e.g. the development of renewable energy sources, advancements in technology, solutions for sustaining the environment and improving healthcare; and to
- deliver and maintain infrastructure that is needed to produce socio-economic growth.

THE NATURE OF THE CIVIL ENGINEERING SKILLS SHORTAGE IN SOUTH AFRICA

Understanding where the shortages occur

The Lawless (2005) survey found that there was a shortage of mid-career civil engineers, i.e. suitably qualified, registered and experienced engineers. CESA's statistics shown in Table 2 suggest that a shortage for such personnel still exists, despite an underutilisation of the current capacity of the consulting industry. This can in part be explained by the age profiles of the members of SAICE and the Institution of Structural Engineers (IStructE), a London-based international organisation, as shown in Figure 1 (Watermeyer 2006). The average age in 2005 of a SAICE member was 52 and of a Fellow 58 (senior member of the profession). By way of comparison the Terblanche (1971) survey indicated a median age of 39.1 years for economically active civil engineers. It also indicated that 21.6,

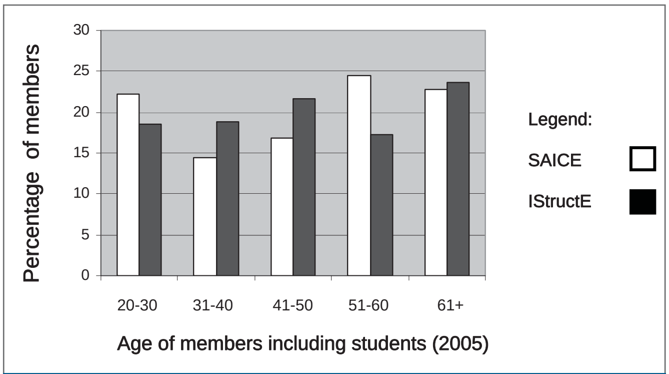

Figure 1: Age profile of SAICE and IStructE members (Watermeyer 2006)

29.6, 29.9, 13.6 and 5.3% of such engineers fell into the age groups <30, 30-39, 40-49, 50-59 and >60 respectively (see Figure 1).

The sharp drop in mid-career engineers in the 2005 statistics from the 1967 industry profile is prevalent in both SAICE's and IStructE's membership, probably caused by the introduction of computers in the 1970s, which reduced the demand for civil engineers and opened up an alternative career path for those wishing to pursue a career in computer engineering and related fields. The steeper drop in the case of SAICE can be attributed to emigration in the wake of the dismantling of apartheid and economic globalisation.

The Construction Industry Development Board (CIDB) published in 2007 a discussion document to portray the state of skills in the industry, identify the skills provisioning challenges and mobilise the industry to contribute to skills development in response to government's large infrastructure spending programme in 2005. The CIDB in order to interpret the additional demand for skills, and to place the skills challenge in context, differentiated between:

- "scarce skills", i.e. those skills which are in short supply but which can be obtained through short-term targeted training, and
- "critical skills", i.e. particular high-level skills within certain occupations.

The CIDB concluded from case studies that the largest demand for skills is in the scarce skills categories, which can be met through short-term targeted training. Critical skills, on the other hand, are required in much fewer numbers, but require up to 10 to 20 years of experience. The CIDB did pinpoint that the shortages in the public sector were reflected particularly at the point of delivery in local government and in the private sector where the lack of experienced site managers was seen to undermine delivery in terms of expected time, cost and quality requirements. They also drew attention to the issue of client delivery capacity. They pointed out that while there may be sufficient numbers employed, many of the individuals in the sector lack the critical skills, knowledge and experience to effectively manage and ensure the delivery of infrastructure in terms of requisite standards of cost, quality and time. In this regard, this discussion paper pointed out that almost 40% of the senior officials and managers in the public sector have five years or less experience.

Researchers at the Duke University (2005) see two main tracks for engineering graduates, namely dynamic engineers and transactional engineers, as opposed to the current categorisation of many countries, including South Africa, into "professional engineer," "professional engineering technologist" and "professional engineering technician". Dynamic engineers are those "*who are capable of abstract thinking, solving high level problems using scientific knowledge, thrive in teams, work well across international borders, have strong interpersonal skills and are capable of leading innovation.*" On the other hand, transactional engineers, although they may possess engineering fundamentals, are not seen to have the experience or expertise to apply this knowledge to complex problems. They are viewed as being largely responsible for "*rote and repetitive tasks in the workforce*". Quality of education is seen to be a major factor in the breeding of dynamic

Table 4 Change in distribution of technologists and engineers in South Africa over time (after Terblanche 1971, and Lawless 2005)

Employer	Percentage distribution (%)	
	1967	2005
State-owned enterprises	12	6
Government including provincial	12	4
Local government	15	10
Consultants	31	51
Industry or business	28	23
Academia	2	6

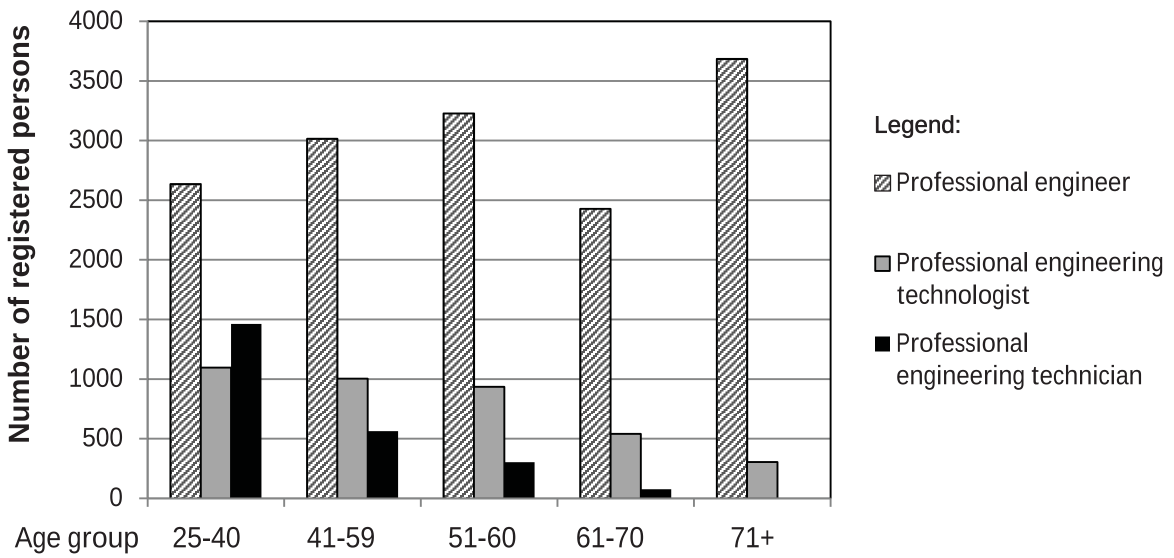

Figure 2: Age profile of the different categories of engineers registered by ECSA in 2011 (Franks 2011)

engineers. Accordingly, not all professional engineers are dynamic engineers. However, dynamic engineers are more likely to be found in this grouping of engineers.

The Duke University's categorisation may be likened to that of the CIDB, i.e. transactional engineers equate to the scarce skills category and dynamic engineers to the critical skills category. Where the two approaches to defining the skills sets differ, is that 10 to 20 years of experience will not convert transactional engineers into dynamic engineers. It can, however, improve the quality and quantity of transactional outputs. In practice there will also be a number of engineers that fall somewhere between these two basic types of engineers.

The distribution of skills shortages

The National Planning Commission (NPC 2011) has recently pointed out that "*transformation in the post-apartheid state required that the racial monopoly over skill be challenged and dismantled.*" Their analysis of the current state of play within government on the outcome of this imperative is that "*the result has been a reduction in the number of professionals available to the state, and a looming crisis in the generational reproduction of professional expertise as the ageing cohorts continue to leave the system.*" The NPC also recognises that "*this skills deficit has an adverse impact not only on frontline service delivery…. but also on the ability of government to engage in long-term planning, coordination across institutions, run efficient operations, ensure adequate maintenance of infrastructure, establish organisational systems and routines, and manage personnel and industrial relations.*"

Table 4 presents a rough comparison of the distribution of engineers and technologists in South Africa in 1967 and 2005 by comparing the figures published by Terblanche (1971) and Lawless (2005). What is clearly evident from Table 4 is that there has been a major flow of engineers from the public sector to the consulting sector over time.

The NPC (2011) also makes the observation that "*many short-term responses to skills shortages do little to address long-term capacity constraints. Consultants can be brought in to design and build infrastructure, but without in-house technical expertise provincial and local governments lack the capacity to ensure the work is done to an adequate standard or to maintain the infrastructure once the work has been completed.*" The NPC proposes to rewrite the story of South Africa by addressing nine key development goals. Five of these goals relate directly to infrastructure development, namely job creation, improving infrastructure, transforming urban and rural spaces, anti-corruption and transitioning into a green economy. Such a plan, however, is only credible if its delivery mechanism is viable. While government can easily outsource transactional engineering work, it cannot outsource its planning responsibilities and its overall technical management of the delivery and maintenance of its infrastructure. Dynamic engineers are required within government to oversee this and make the necessary judgement calls. These skills are, however, always in demand in all sectors.

STRATEGIES TO ADDRESS THE CIVIL ENGINEERING SKILLS SHORTAGE

Strategies to increase the supply of critical skills

The 1971 and 2005 strategies to address the shortages of engineers focused on increasing the number of civil engineers, i.e. the supply.

More recent strategies have, however, focused on developing the skills and experience of graduate engineers through structured programmes, to enter the profession by becoming registered with ECSA. These strategies need to be continued. However, the number of graduates required at an entry level to the profession needs to be reconsidered, as the supply appears to be outstripping the demand. South Africa does not require a tenfold increase in its number of engineers, as has been suggested in recent years.

The 2011 age profile of registered engineers of all disciplines in the three categories of engineers registered by ECSA is as shown in Figure 2 (Franks 2011). Table 2 indicates the fluctuating demand for the various categories of registered engineers. Critical questions need to be asked regarding the numbers required in each of the three streams. The demand for professional engineers amongst consulting engineering firms appears to be higher than for the other two categories. Given the findings of the Duke University regarding the linkage between education and dynamic engineers, priority should be given to developing more professional engineers who have greater potential to become dynamic engineers in preference to the other two streams.

Reducing the demand through more efficient practices

With the notable exception of the 2007 CIDB report, what has not been explored is making civil engineering practice more efficient as a measure to reduce the perceived demand. The CIDB 2007 report suggested in this regard:

- the packaging of public sector projects into large multi-year contracts which require fewer skilled and experienced people within government to procure, manage and administer; and reducing the professional inputs in the design and supervision of the works, as well as the on-site management of the works through economies of scale; and
- standardisation of procurement documentation, designs, specifications, procurement, pricing, contracting and targeting strategies within particular infrastructure programmes, which would significantly reduce the internal and external professional inputs required to deliver projects.

Evidence in the health sector in South Africa has, for example, indicated that quality health care can be delivered in the face of severe staff shortages and in resource-limited contexts. Organisational routines and protocols which encourage coordinated efficiency and enable staff to understand their respective roles and responsibilities within an established system when underpinned by teamwork, job satisfaction, commitment to the job and a focus on communication and relationships have overcome such constraints (Watermeyer 2012). There is no reason why similar strategies cannot likewise enable the delivery of engineering works in the public sector in the face of staff shortages and other resource constraints.

Public sector strategies, in addition to those already identified by the CIDB, which have the potential to improve efficiencies and reduce the demand for professional inputs include:

1) Enter into long-term collaborative relationships, e.g. by entering into target cost or management framework contracts (Watermeyer and Thumbiran 2009; Watermeyer 2010).
2) Integrate design and construction in projects by either assigning more design responsibilities to contractors or engaging contractors earlier in projects (when not more than 25% of the design is complete) (Watermeyer 2010).
3) Adopt a comprehensive, uniform and systematic system for the delivery and scheduled maintenance of public infrastructure, such as that embodied in the CIDB and National Treasury IDM Toolkit (2010) (Infrastructure Delivery Management System) which:
   a) is capable of being documented and implemented in accordance with the requirements of ISO 9001 *Quality management systems – requirements*, and
   b) instil what Greenhalgh (2008) describes as routine (a repetitive, recognisable pattern of independent actions, involving multiple actors) which reduces uncertainty.

Accelerating the development of critical skills

A key question that needs to be asked, is how the current experience gap can be narrowed, i.e. what is the quickest way to convert scarce skills into critical skills, particularly in the public sector. The starting point is to identify what role government wishes to play in the delivery and maintenance of infrastructure. The NPC (2011) has indicated that government needs to assume responsibility for planning, and the management of the delivery and maintenance of infrastructure – it cannot outsource these responsibilities.

There is a dearth of documented civil planning practices and related technical literature that is aligned to the South African environment. Government has documented their Infrastructure Delivery Management System (CIDB and National Treasury 2011) and has only started to develop comprehensive guidance on the implementation of a range of alternative contracting strategies. The basic standards of materials and workmanship, SANS 1200 standardised specifications for civil engineering works, are geared for the traditional approaches to delivery and have in the main not been updated since the 1980s (Watermeyer *et al* 2012). Government as client has in the past led the development of standards to serve their infrastructure needs. With the erosion of its technical capabilities, such standards have either not been updated for several years or have simply disappeared or are not included in procurement documentation. There is a particular need to document uniform standards for municipal services, preferably in the form of national standards in order to satisfy international trade obligations.

The South African Bureau of Standards (SABS) is, according to the Standards Act 2008, the peak organisation for standardisation. SABS currently has neither the technical leadership nor technical capabilities to update and develop the volume and nature of the standards that are required. The Act does, however, make provision for SABS to appoint Standards Development Organisations to develop South African national standards in accordance with specified criteria. Learned societies and industry associations need to become Standards Development Organisations, or to participate in these, in order to provide the necessary technical leadership and expertise to develop the much needed national standards.

ECSA currently registers engineers at the point of entry into the profession, based on academic qualifications and not on postgraduate qualifications. It does not register or recognise basic specialisations, such as geotechnical engineering, structural engineering and transportation engineering, let alone specialist skills relating to practice areas such as construction procurement, public sector delivery management, planning, etc. Learned societies and industry associations need to fill this vacuum and publish specialist lists, i.e. non-statutory voluntary listing of professionals who have met a defined standard of competence in a specialist area, typically administered by a professional or trade body. Such bodies will also need to train, mentor and develop their members' skills to reach the required standard of competencies.

Strategies that need to be considered by learned societies and industry associations to accelerate the development of critical skills include the following:

- Produce civil engineering standards and tools to support practice, including South African national standards.
- Develop planning skills, tools, techniques, etc, which are capable of integrating with and being understood by other disciplines and decision-makers.
- Accredit and recognise specialist civil engineering skills, including those relating to planning, procurement and delivery management.
- Publish in communications with their constituents (e.g. in monthly magazines and newsletters and on websites) articles on professional guidance and technical aspects which would provide information on everyday matters affecting civil engineering practice.

CONCLUSIONS

The civil engineering profession plays a major role in the growth and development of a country's economy. It is experiencing a shortage of engineering skills, the quantum of which is not known or well understood. There is no simple answer to the question of how many civil engineers are required to meet present and future demands. There are a number of factors which need to be considered when attempting to answer this question, including current levels of utilisation, the type and quality of engineering professionals that are required, the state of the economy, the demand for infrastructure, procurement strategies that are used to deliver infrastructure and the infrastructure delivery management system that is used by government to deliver and maintain infrastructure.

There is a need to broaden the range of strategies that have been employed to date to address the current shortage, particularly in the public sector. Demand-side strategies aimed at reducing the demand on the services of civil engineers also need to be considered, alongside those aimed at increasing the number of entrants to the profession (critical skills) and the retention of existing skills. Strategies also need to be put in place to accelerate the gain in experience in order to address the need for critical skills, to in turn address the mid-career deficit in skills.

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