# A FORMAL PROGRAM TO DELIVER EXPERIENCE CIVIL ENGINEERING PROFESSIONALS

A possible solution towards Skill Shortage and Infrastructure Development Skills needs in South Africa, Africa and other Developing Countries

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**Abstract:** South Africa and the African continent are currently experiencing a critical skills shortage within the civil engineering and construction industry. This and the current international economic down-turn are putting strain on infrastructure development and construction within developing countries. By delivering high quality civil engineering professionals to the infrastructure development and construction environment and by equipping those engineers with the correct capabilities, this problem can in time be resolved. This paper presents a possible contribution, in the form of a structured three year program, towards solving the above mentioned problem. The proposed program will be aimed towards offering further development for graduate civil engineers. This solution will include the assistance towards professional registration; delivering an academic program that is both focused on engineering and construction management tools and techniques, as well as delivering corporate and strategic principles. Structured work experience and mentoring will also play an important role in the proposed program. The aim of such a program would thus be to: Supply the civil engineering and construction industry within the public sector with experienced professional engineers with academic and practical experience in infrastructure development and management skills. The solution will include partnering with leading tertiary academic institutions, with large industry role players, both in the construction and consulting environment, and with government and municipal institutions.

**Keywords:** *local government; municipal engineer; skill shortage; professional development; engineering mentorship*

## 1.0 Introduction

South Africa is currently experiencing a critical skills shortage within the engineering industry. This is particularly the case in the infrastructure development and construction environment and amongst the civil engineering sector.

This paper takes a look at this need for skills and the impact it has on the infrastructure of a developing country. A proposed program is presented to serve as a solution towards this problem. The aim of the proposed program is to increase the number and quality of civil engineers working in a project management and coordination capacity in the infrastructure development and maintenance environment within the public sector.

This paper focuses on civil engineers and their responsibility within the mentioned environment. Although mechanical and electrical engineers are also involved in infrastructure development, they are not covered as part of this paper.

## 2.0 Critical Skills Shortage

### *2.1 Skills Needs*

According to Daniels (2010) two types of critical skills exist within the South African context. The first refer to generic skills which could include aspects such as problem solving, science and mathematics skills. The second relates to a particular occupational skills required within an occupation. The first is a problem to be addressed at school and tertiary education level. The latter will be referred to further in this paper.

With the above mentioned in mind, it is generally accepted in South Africa that a critical skills shortage, type two mentioned above, does currently exists in the engineering environment. This was confirmed in Parliament by the South African Education Minister (Motsheka, 2011) when she said that Engineering Sciences is amongst the list of critical skills shortages and areas identified for further development on tertiary level.

McKenchnie (2008) also confirmed this fact saying that South Africa is faced with a chronic skills shortage in the engineering sector. He goes further by saying that the problem is multi-faceted and is a result of the following facts:

• Historically the South African population were educated and developed disproportionally as a result of past apartheid regulations.

• A global demand for skilled engineers resulted in the immigration of South African engineers abroad.

• Deficiencies in primary and secondary education systems resulted in insufficient mathematics and science candidates, which in turn resulted in low numbers of students following tertiary education in the engineering sector.

This skill shortage can particularly be found in the civil engineering and construction industry where the current ratio for one civil engineer to the population is 3166 (Ashpole,

2011). He compares this figure to countries such as Norway and Germany where the number is 120 and 217 for one civil engineer respectively.

### *2.2 Professional Engineers*

In South Africa the engineering profession is regulated by the Engineering Council of South Africa (ECSA). The council was established in terms of the South Africa Engineering Professional Act, 2000 (Act No 46 of 2000) (About ECSA: What is ECSA [s.a.]). Engineers who which to practice as a professional engineer (Pr.Eng) are required to submit a formal application, take part in a Professional Review and undergo a formal Experience Appraisal (Discipline specific guidelines: Civil engineer [s.a.]).

Engineering activities are essential and beneficial to society and a country's economy, and these activities should be carried out by professional engineers. They are responsible for various infrastructure systems which form the basis of human rights and society development (ECSA Annual Report 2010/11, 2010:6). In this light it is disturbing to notice that the net growth in professional registered civil engineers between 2005 and 2012 are only +19 engineers (Nortje, 2012).

### *2.3 Public Sector*

Civil engineers are responsible for the design and construction of infrastructure. They also play an important role in the planning and management of infrastructure. The knowledge and skills to develop, manage and maintain this infrastructure are captured in the sup-discipline of civil engineering called Municipal/Urban engineering (Engineering: Issues challenges and opportunities for development, 2010:124).

Municipal engineers are involved in specifying, designing, constructing, maintaining and planning of municipal infrastructure (or basic services infrastructure) such as streets, sidewalks, water supply networks, waste water networks, storm water infrastructure, solid waste disposal and many more. Their responsibilities also include the planning, constructing, maintaining and management of local distribution networks such as electrical and telecommunication services. Optimisation and long term systems planning also form part of the municipal engineer's responsibilities (About us – IMESA [s.a.]). Municipal engineers clearly require a broad base of experience and knowledge which include management and technical fields.

According to the Constitution of South Africa, Section 152.1 and Section 152.2, local government is the delivery point for basic services and infrastructure. Its objectives, amongst others, are listed as follow:

- Ensure the provision of services to communities in a sustainable manner.

- Promote social and economic development.

- Promote a safe and healthy environment.

The civil engineer and local government thus share the same responsibilities in this regard. These responsibilities are to plan, design, construct, maintain and operate infrastructure, while improving existing infrastructure and ensuring environmental health and safety to the public.

In 2007 a study was conducted by Lawless (2007: 321) to assess the shortages of civil engineering professionals in the public sector of South Africa. The study showed, amongst others, the following statistics in regards to civil engineers working in local government:

- From the 283 municipalities present in the country that year, 83 employed no civil engineering professional.

- Civil engineering vacancies at the time were in the order of between 40% and 60% (Lawless, 2007:321)

- Only 32% of professional civil engineers resigning that year were replaced.

It can consequently be derived that a significant absence of engineering professionals are being experienced in the public sector, which is by law responsible for the development and maintenance of infrastructure.

From the discussion above it is clear that South Africa is currently experiencing a severe skills shortage within the engineering environment. This is particularly the case within the public sector and amongst civil engineers. Furthermore, it is clear that civil engineers are not registering professionally at a rate expected. The result is that the public sector ceases to maintain its ability to manage government infrastructure and government infrastructure spending (Skills for infrastructure delivery in South Africa, 2007:2). This fact was again highlighted in February 2012 when the South African Minister of Finance (Gordhan. 2012) indicated that from the R 260 billion budgeted for spending on government infrastructure, only R 178 billion, or 68%, was spent in the 2010/2011 financial year. In his budget speech he explicitly indicated that this low number is as a result of state enterprises, municipalities and other government departments not having adequate capacity to keep up with government infrastructure spending.

In 2007 the Construction Industry Development Board (CIDB) confirmed the fact that government departments lack capacity to spend government funding (Skills for infrastructure delivery in South Africa, 2007:2). The CIDB furthermore state that this

lack in capacity is a result of a few factors, namely: insufficient numbers employed; lack of critical engineering skills; lack of knowledge; and lack of relevant experience to effectively manage and ensure delivery of infrastructure. A closer look will now be taken of the impact on the condition of South African assets of this inability to manage, maintain and develop infrastructure.

## 3.0 Condition of South African Infrastructure

Every five years, the South Africa Institute of Civil Engineers (SAICE) publish an Infrastructure Report Card (IRC). The IRC is a document that reports on the state of engineering infrastructure within South Africa. The report highlights the observations of the professionals responsible for the planning, construction, operation and maintenance of South African infrastructure (SAICE Infrastructure report card for South Africa, 2011: 4).

In 2011 SAICE published the second IRC. The 2006 IRC contained nine built environment infrastructure sectors, namely: water services, sanitation and wastewater services, solid waste management, roads, airport, ports, railways, electricity generation and distribution and hospitals. In 2011 the IRC included two new sectors, namely Public Ordinary Schools and Fishing Harbours. In the study the condition of the infrastructure is assessed and graded with the following scale: A = World Class, B = Fit for the future, C = Satisfactory for now, D = At risk, E = Unfit for purpose. Tab. 1 is an abstract from the 2011 IRC and shows the results of both the 2006 and 2011 report.

Tab. 1 clearly shows that although a slight improvement was made in the condition of the infrastructure from 2006, most of the sectors are still graded as Satisfactory for now or At Risk, which does not reflect well on the current condition of South African infrastructure.

It can thus be argued that the lack, and decrease in numbers, of civil engineering professionals has a negative impact on the condition of South African infrastructure. A need is thus identified to increase the number of civil engineers responsible for the development and maintenance of infrastructure. These engineers should be equipped with the skills and knowledge to construct, manage and maintain infrastructure.

The above mentioned need can be satisfied by introducing a structured program to deliver these engineers. The objective of such a program would be to supply the public sector with high volumes of experienced professional civil engineers containing knowledge and skills in the infrastructure development and management environment.

Such a program would be in contrast to existing practice were most civil engineers follow one of either two career paths. The first is for young civil engineers to be employed by either an engineering consultant or a civil engineering contractor. These

engineers make their careers in private sector organisations and in many cases become technical specialists. The second career path involves graduate engineers working for public sector organisations (in limited numbers). In many cases these engineers are forced in infrastructure management roles early in their careers. The challenge here is that in many cases these engineers lack strong technical foundations.

Another challenge that is currently being experienced in the latter case is that as a result of the lack of experienced in senior municipal engineers, very little, or none, planning and management knowledge are transferred to junior engineers. The result is that senior municipal engineers advance to management positions without having acquired sufficient technical implementation skills or planning and management skills and experience (Lawless, 2007:260).

The motivation for the proposed program is therefore to fill the gap that currently exists in the public sector, namely: to supply the public sector with engineers which are both technically competent and has the ability to plan and manage public sector infrastructure systems.

Table 1: Infrastructure Condition Assessment & Improvement

| | Sector | 2006 | 2011 | Trend |
|---|---|---|---|---|
| 1 | **Water services** | | | |
| | *Department of Water Affairs Infrastructure* | D+ | D- | ↓ |
| | *Major Urban areas* | C+ | C+ | → |
| | *All other areas* | D- | D- | → |
| 2 | **Sanitation services** | | | |
| | *Major Urban areas* | C- | C- | → |
| | *All other areas* | E | E- | ↓ |
| 3 | **Public schools** | | D+ | |
| 4 | **Roads** | | | |
| | *National* | C | B | ↑ |
| | *Paved provincial* | D- | D- | → |
| | *Paved metropolitan* | D- | C- | → |
| | *Paved district and local municipal* | D- | D | → |
| | *All gravel roads* | D- | E | → |
| 5 | **Electricity** | | | |
| | *ESKOM generating* | C+ | C+ | → |
| | *ESKOM's transmission network* | C+ | B- | ↑ |
| | *Local distribution* | C+ | D | → |
| | **OVERALL** | D+ | C- | ↑ |

Source: SAICE Infrastructure Report Card, 2006 & 2011

## 4.0 Proposed Program

The strategic objective of the program proposed here is to improve national service delivery within developing countries by assuring quality constructed and well managed infrastructure. A second objective is to improve on the skill shortage that is currently being experienced in this environment. The solution will be presented as a formal structured program. The duration of the program be three years, and will consist of, and be supported by three pillars, namely: Academic and Skills Development; Work Experience and Mentorship and; Professional Registration. These three pillars will now be further discussed. Candidates for the program will consist of graduate civil engineers.

### *4.1 Academic and Skills Development*

As part of the process, it will be expected of candidates to take part in and pass an academic program. Candidates will have to attend academic block-weeks offered twice a year. During such a block-week the candidates will take part in lectures, class- and group discussions, do presentations and participate in workshops.

Candidates attending the block-weeks will receive assignments due for completion at the following academic block-week. The time between block-weeks will be utilised by the candidates to prepare for assessments that will take place at the start of each academic block-week. The academic program will be outcome based and all lectures and information sessions will have a strong integration between theory and practical knowledge.

Cooper et al (2011) identified the following skills set for municipal engineers: local authority finance, local government law and administration, negotiating skills, project management, town planning, skills to operating within a multidisciplinary environment, presentation skills and cost benefit studies. By taking in consideration this skillset a list of potential subject were are identified. This list is represented in Tab. 2.

It can be seen from Tab. 2. that the content for the proposed academic program focusses on planning and management of public sector infrastructure, and not on technical implementation thereof.

Courses will be delivered through registered academic institutions. Provision will be made for the courses to be recognised for academic credits. These credits could at a later stage count towards completing a Post-Graduation Diploma (PGD) or a Masters degree. Completing one of these degrees is subject to obtaining sufficient credits and completing a research thesis as per academic standards and procedures.

Courses offered will be in line with ECSA's Policy on Continuous Professional Development, 2007. Courses completed will therefore count towards professional

registration, and form part of the delegate's portfolio of evidence. It will furthermore be expected of the candidates to base all assignments on real life projects and challenges. This will contribute towards integrating the academic offering with the work experience and professional development, which is one of the outcomes of the program.

Further benefits arising from the academic offering and block-weeks, will be for the candidates to be exposed to industry participants and candidates from other year groups. This will facilitate further learning from more experienced peers and contribute towards opportunities to form professional networks.

Table 2: Potential Course Subjects

| **Course Subjects** | |
|---|---|
| Project Management | Human Resource Development |
| Procurement Management | Professional Communication |
| Construction Management | Creativity, Innovation and problem Solving |
| Infrastructure Management | Financial Management & Cost Accounting |
| Engineering Risk Management | Control |
| Engineering Economy | Business Management & Planning |
| Construction Information Technology | Negotiation Skills |
| Construction & Contract Law | Systems Thinking |
| Engineering Environmental Management | Strategic Management |
| Quality Management | Business Integrity Management |

Source: Author

### *4.2 Work Experience and Mentorship*

The second pillar on which the program will be based is to supply the candidates with a solid foundation of structured work experience and mentorship. To gain relevant experience, each delegate will work on two major infrastructure development projects. The exposure to the projects would be 18 months each. During each project the delegate will be rotated between the design office and the construction site to gain sufficient experience on all aspects of a project. A technical project mentor will be assigned to each delegate for the duration of the project to assure relevant experience and maximum exposure.

After the completion of a project, it will be expected of the candidates to complete a Project Experience Report. The report will consist of a technical section, which will

include reporting on technical lessons learned and skills acquired, and a non-technical section which will include aspects such as professional development gained. The report will form part of the portfolio of evidence which in turn form part of the professional registration process.

Apart from assigning a technical mentor to each delegate on each project, it will be expected of the candidates to participate in a structured mentorship program. This program will run for the full three years. Each delegate will be assigned to a mentor who will preferably remain with that delegate for the full duration of the program. Regular, structured mentorship meetings will be held to discuss aspects such as lessons learned and goal setting.

One of the responsibilities of the mentor is to provide feedback to the program organiser on the relevance of the delegate's work experience and the projects that he/she is working on. Mentors will be funded through the program and will consist of retired engineers and project managers within the civil engineering and construction environment.

As mentioned earlier, the work experience and mentorship part of the program will not only contribute towards the outcomes of the program, but will form part of the professional registration process, which forms the third pillar on which the program is based.

### *4.3 Professional Registration*

As part of the application towards professional registration, it is expected of a candidate engineer to submit a 4 000 words Project Report, evidence of all experience gained, evidence of all training, proof of mentorship and proof of continuous learning. The program is structured to support these requirements and will be timed that by the end of the delegate's third year all the ECSA requirements to register professionally will be achieved.

ECSA indicates in its guidelines that the minimum requirement to register professionally is to obtain relevant work experience of not less than three years. The planned three years' work experience and mentoring program indicated above is thus in line with ECSA's requirements. The program will ensure engineers are not caught up in certain aspects of engineering with the consequence of stagnating and not gaining the range of experience as required.

## 5.0 The Stakeholders

Stakeholders from three spheres will be involved in the program, namely The Public Sector, Industry and Academic Intuitions. The role of these stakeholders is now further discussed.

### *5.1 Public Sector*

The public sector will be involved in two major ways. The first is to identify potential infrastructure development projects on which candidates could obtain experience. Candidates will be employed by either engineering consultants or contractors. The candidates will consequently gain relevant experience through its involvement in major public sector projects.

Funding is required for the academic program and to employ mentors in the mentorship program. The second involvement of the public sector is to supply this funding. These funding requirements will be achieved through government funding initiatives such as South African Jobs Fund, South African National Skills Fund, South African Expanded Public Works Program and other related initiatives.

### *5.2 Industry*

Industry will contribute towards the program by firstly offering employment to the candidates and secondly by facilitating experience. Each delegate will be full time employed by either an engineering consultant or an engineering contractor. Industry will have to commit to rotate candidates as required and to facilitate full exposure to all aspects of the projects involved.

### *5.3 Academic Institutions*

The role of the academic institutions is to supply the academic infrastructure offered throughout the program. This will be done by offering courses designed specifically to achieve the goals of the program. Further involvement is required to structure the content of the academic offering to such an extent that it can ultimately contribute towards the required academic credits for a PGD or a Masters degree.

Although the program is designed to stand alone as a separate entity, an option is to locate the program in an existing academic institution by means of a funded Chair. The implications of this will be that the Chair will not only be responsible for academic delivery, but the administrative responsibilities will also fall within the responsibilities of such a Chair. By seating the program in a Chair, the possibility for further research and academic content development is guaranteed.

## 6.0 Key Success Factors

To ensure the success of the program, the following success factors have been identified: Funding and government buy-in; industry involvement and commitment and; recruiting mentors. Before further development on the program can take place involvement of the above mentioned collaborators have to be confirmed.

## 7.0 Further Research

The proposed academic offering is based on preliminary industry interviews and existing professional development programs. Further study in this regard is required to determine the specific skills and knowledge needs for such a program. The study will consist of obtaining primary data from various municipalities, nationally and internationally, as well as an in depth analyses of the data and findings.

## 8.0 Conclusion

In this paper the skills shortage that is currently being experienced in the engineering industry are identified. The impact of this shortage is further quantified by considering the state of South African basic service infrastructure. From this, the need for a formal program was identified to deliver civil engineers practicing in infrastructure development, management and maintenance.

The identified program includes guiding graduate civil engineers through a structured process of academic learning and relevant work based experience. The program also includes a structured mentoring process.

As a conclusion it can be said that if such a program can be launched and implemented successfully with the buy-in from all stakeholders, it could offer a solution towards sub-standard service delivery in developing countries. This could have a positive impact on economic and social development within these countries.

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