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ENGINEERS FOR AFRICA

Identifying engineering capacity needs in Sub-Saharan Africa

Supporting document 1: Literature review

About the Africa-UK Engineering for Development Partnership

The Africa-UK Engineering for Development Partnership (A-UK) brings together the engineering community in Africa and the UK in a consortium comprising the Africa Engineers Forum, The Royal Academy of Engineering, the Institution of Civil Engineers and Engineers Against Poverty. The aim of the Partnership is to strengthen the capacity of the African engineering profession and promote mutually beneficial links between engineers in Africa and the UK.

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This study was made possible by the kind support of the Anglo American Group Foundation, Schlumberger and the David and Elaine Potter Foundation.

1. Introduction and structure

This literature review is part of a broader study to improve understanding of *capacity building* needs in the engineering sector in Sub-Saharan Africa (SSA), in support of the A-UK partnership. The literature review is complemented by two additional research tools: an electronic capacity building needs survey distributed to practicing engineers and decision-makers in the engineering sector in SSA and a series of semi-structured interviews with senior figures in the engineering profession. The results of the survey and interviews are discussed in the Research Summary Report.

The term *capacity building* emerged in the lexicon of international development during the 1990s and is today included in the programmes of most international organisations that work in development. Wide usage of the term has resulted in controversy over its true meaning, but for the purposes of this study it is used to refer to strengthening the skills and competencies of people and communities in developing societies. The United Nations Development Programme notes that capacity building takes place on an individual level, an institutional level and the societal level. [1]

In order to understand capacity building needs, evidence is needed of current weaknesses. There may be a quantitative problem, for example, an insufficient number of engineers graduating from the universities or technical colleges to fill the posts available. Alternatively, or additionally, there may be a qualitative problem: an insufficient number of engineers with the required mix of knowledge, skills and competences, most of which are developed through experience.

The literature review aims to summarise existing information on the following:

1) The scale and nature of shortages of engineering skills in various countries of SSA
2) The underlying causes of the shortage of engineers and relevant engineering skills
3) The impact of these shortages on industry and the economy
4) Recommendations for strategies to reduce skills shortages

A word of caution is required. This is an incredibly complex issue. Sub-Saharan Africa is a vast region, comprising more than 40 countries. Each country in SSA (and each region within each country) has its own particular economic, social and institutional characteristics, making it difficult to extrapolate findings from any one region or country to the whole continent. At the same time, engineering is divided into different fields (civil, mechanical, electrical, chemical, agricultural etc.) and engineering skills may be required at various different levels (research, management, professional, technician). As UNESCO (*Engineering report* 2010) has pointed out, the demand for engineers will vary by sector, field and level over time and across countries as technologies and industries develop and decline. The issue is further complicated by different definitions of what is an engineer. While the term is commonly used to refer to graduates in engineering, or to

[1] *United Nations Economic and Social Council* **Definition of basic concepts and terminologies in governance and public administration**. http://unpan1.un.org/intradoc/groups/public/documents/un/unpan022332.pdf

those graduates who are registered with the appropriate body, in some countries the term may include anybody who exhibits some level of technical skill (*ibid)*.

Literature search methodology

The resources available for this study were not sufficient to carry out an extensive literature search and carefully structured narrative that a comprehensive review would entail. The focus is confined to the engineering sector and the situation in SSA, meaning that lessons that could have been learned from other parts of the world that have successfully enhanced capacity in the engineering sector, as well as lessons from other technological sectors such as applied science, were not included. Further, it is likely that a more comprehensive picture would have emerged if sufficient time had been available to make requests for data to the relevant government departments in individual countries.

Given these constraints and the conspicuous lack of available data, requests for further data were sent to key organisations and individuals (see below) including six SSA-based professional engineering institutions.[2] These organisations are typically involved in regulating and promoting the interests of the profession and could reasonably be expected to know if data existed that was relevant to their national and regional situations. All requests were answered, but no additional material data was identified.

Relevant literature was identified by:

1) Searching Google and Google Scholar using the terms 'engineer' AND 'Africa' AND ['capacity' OR 'skills'];
2) Requests to key organisations and individuals with expertise in this area for advice on specific documents and the best places to search;
3) Searching the journals and websites recommended by colleagues;
4) Snowballing from the references / bibliography of relevant documents found;
5) A direct request for information sent to all Institution of Civil Engineers (ICE) representatives in African countries.

Structure

Section two of this review describes the type of literature that has been included in the review. Sections three to six summarise the material found on each of the four topics listed above. Section seven discusses gaps in the literature and section eight concludes.

2. Literature included in the review

A total of 30 documents have been included in the review. These include seven studies from South Africa, two from Nigeria, one from Rwanda and a series of studies briefly

[2] The six institutions were: Ordemo dos Engenheiros of Mozambique; Engineering Professions Association Namibia; Institution of Engineers Tanzania; The Institution of Engineers of Kenya; Zimbabwe Institution of Engineers; The Engineering Institution of Zambia

covering capacity issues in Tanzania, Uganda, Kenya, Mozambique and Malawi. The remaining studies are not confined to one geographical region. A summary of the types of literature included is given below:

- Two books published by the South African Institution of Civil Engineering (2005 & 2007). These are the *Numbers and Needs* studies commissioned and overseen by Allyson Lawless FREng during the period when she was President of the South African Institution of Civil Engineering (SAICE). This study remains the most comprehensive examination of the state of the civil engineering profession anywhere in SSA.
- An extensive report published by UNESCO entitled *Engineering: Issues, Challenges and Opportunities for Development* (2010).
- A report published by UNESCO entitled *UNESCO Science Report 2010* (2010).
- A peer-reviewed journal paper on *Addressing South Africa's engineering skills gap* (a four-page case study from a consulting company) (2009).
- Three papers from the American Society of Civil Engineers' Journal of Professional Issues in Engineering Education and Practice (two from 2008 and one from 2004)
- A paper from the journal of SAICE on the topic of talent management in the South African civil engineering consulting industry (2010).
- A report published by the Construction Industry Development Board (CIDB) and the South African Department of Public Works on *Skills for infrastructure delivery in South Africa* (2007).
- A report published by the South African Association for Consulting Engineers (SAACE) entitled *State of the South African Consulting Engineering Profession in South Africa* (2007).
- A conference paper by two South African engineers which examines public sector constraints to infrastructure delivery, and proposes alternative methods of delivering at scale (2009).
- A report published by the Scottish Institute of Sustainable Technology (SISTech) and UNESCO on the subject of engineering capability in Rwanda (2009).
- A New Partnership for Africa's Development (NEPAD) preliminary study on engineering education (2008).
- A World Bank paper on *Skills Development for Economic Growth in Sub-Saharan Africa* (2010).
- The Royal Academy of Engineering Hinton Lecture given by Calestous Juma HonFREng on the topic of the role of engineering in international development (2006).
- The Royal Academy of Engineering publication *Engineering Change: Towards a sustainable future in the developing world* (2008).
- A series of studies undertaken for DFID in 2002 by the UK Institution of Civil Engineers (ICE) and Global Development Consultancy (GDC) as part of a project to strengthen professional engineering associations in eight countries, four in Asia and four in Africa.[3] The reports produced under this project that have been reviewed are the following:
    - *Report on the proposed development of the engineering profession in Tanzania* by ICE/GDC (2002a)

[3] The DFID contract number was AG 2700. The proposals were never implemented

   - *Report on the proposed development of the engineering profession in Mozambique* by ICE/GDC (2002b)
   - R*eport on the proposed development of the engineering profession in Uganda* by ICE/GDC (2002c)
   - *Report on the proposed development of the engineering profession in Malawi* by ICE/GDC (2002d)
   - *Report on the proposed development of the engineering profession in Kenya* by ICE/GDC (2002e)
   - *Strengthening the capacity of local consultants in Tanzania: Report and recommendations* by Andrew Hollway (2000)
   - *Strengthening the Uganda institution of professional engineers: Report and recommendations* by Andrew Hollway (1999)
- A guide for companies involved in local procurement by the International Finance Corporation in collaboration with Engineers Against Poverty (2011).
- A guide to developing a local content strategy by IPIECA in collaboration with Engineers Against Poverty (2011).
- A book on local content in procurement by Dr Michael Warner (2011).
- A research paper on the petroleum industry and local industrial development by the Institute for Research in Economics and Business Administration.
- The Millennium Project *Final Report of Task Force 10 on Science, Technology and Innovation* by Calestous Juma HonFREng and Dato' Ir Lee Yee-Cheong (2004).
- A report entitled *Africa's Infrastructure* by Vivien Foster and Cecilia Briceño-Garmendia (2010).
- A report by the OECD entitled *Infrastructure to 2030* (2007).

The selection of literature identified is striking in a number of ways. First, only one peer-reviewed academic paper was found that is relevant to the topic (and that is a four-page case study) leading to the conclusion that little rigorous academic work has been carried out in this area. Second, seven of the 30 documents reviewed relate to South Africa: only one country-specific study containing facts and figures that is not focused on South Africa was found – the SISTech-UNESCO study on Rwanda (referenced as Goodsir et al., 2009). Third, the major study from South Africa and many of the other studies focus on civil engineering and the skills needed for the construction of infrastructure. The lack of literature in relation to other engineering disciplines results in a bias towards civil engineering in this review, though it should be acknowledged that this might be a reflection of a predominance of civil engineers in most African countries.

Finally, the extent to which engineering capacity is reflected in broader discussions of engineering and technology appears to vary considerably. In addition to the papers and reports selected because capacity was an obvious focus, documents dealing more broadly with engineering and technology issues were also consulted because they could reasonably be expected to touch upon engineering capacity issues. While this was true in a few cases, in was not in several others. For example, a substantial report by the Organisation for Economic Cooperation and Development (OECD 2007) entitled *Infrastructure to 2030*, the culmination of a two-year project, said nothing material about engineering capacity.

3. The scale and nature of skills shortages in the engineering sector in SSA

Quantitative issues

The most comprehensive study of skills shortages in SSA that we found was a study of *Numbers and Needs* in civil engineering in South Africa. The study was initiated in 2003 by the South African Institution of Civil Engineering (SAICE). The research determined the number, age, gender and race of all civil engineers, technologists and technicians in South Africa. The aim was to understand current shortages and develop solutions. The findings are split into two books, examining the private sector (Lawless 2005) and the public sector (Lawless 2007) respectively.

A severe shortage of engineers was identified in both sectors. In the private sector over 80% of consulting practices were found to be seeking experienced engineers (Lawless 2005). Similar figures emerged from the South African Association of Consulting Engineers (SAACE) report on the state of the South African consulting engineering profession (2007). The report found that, in December 2005, 76.5% of consulting firms were seeking to increase their numbers of engineering staff. By June 2007 this figure had increased to 91.2%.

The situation in the public sector was even worse, with municipalities reporting 35% vacancies, and metros 45% vacancies (Lawless 2007). 81% of South Africa's local municipalities had no civil engineers in their employ and 35% did not even have a technician. District municipalities fared a little better, with 47% without an engineer and 9% with no technical staff.

A comparison of the distribution of engineers and technologists in 1967 and 2005 confirmed a major flow from the public to the private sector over time (Watermeyer and Thumbiran, 2009). While 39% of engineers and technologists were employed in the public sector in 1967, by 2005 the figure had fallen to 20%. The shift of engineers from the public to the private sector, particularly to consulting firms, clearly reflected a trend to outsourcing which had occurred in many countries. But a minimum number of technical staff was still required to handle procurement on behalf of public sector clients.

The only other country in SSA for which a dedicated quantitative study on skills shortages was found was Rwanda. Goodsir et al. (2009) presented data from a National Skills Audit Report carried out by the Rwanda Human Resource Development Agency (HIDA), published in 2009. The HIDA report identified engineering skills shortages on a huge scale: a 44% shortage of managers and a 72% shortage of professionals. The report also identified skills shortages among academic staff, finding that in the two universities in Rwanda that provide engineering degrees there are staff vacancies and a shortage of qualified staff.

In an earlier study, an extreme shortage of skilled engineers and technicians in all disciplines was noted in Mozambique where the number of indigenous professionals was described as 'totally inadequate', with only 100 graduates each year for a population of 180,000 (ICE/GDC 2002b). Shortages were also noted in Malawi with only 50 graduates each year (ICE/GDC 2002d), as well as in Tanzania (ICE/GDC 2002a).

Some further data on the number of students enrolled and graduating from tertiary education in engineering [4] in SSA was available from the UNESCO (2010) report *Engineering: Issues, Challenges and Opportunities for Development*. The data for countries in SSA is presented in Annex A, as is data for the UK for comparison. Some data is summarised in Table 1. It can be seen that there is a huge difference in the number of students enrolled and graduating in sub-Saharan African countries compared to developed countries. For example, in 2006, 52,798 engineers graduated from tertiary education in the UK, approximately one per 1,100 people, compared with one per 110,000 in Mozambique.

One would expect the UK, as an advanced industrial economy, to require a higher proportion of engineers in the population than a low income country in SSA. Data on the demand for engineers would be needed to make definitive statements on the existence of a shortfall in engineering expertise. However, it seems unlikely that the vast difference revealed by the above data would be justified by the difference in demand for engineering skills.

Table 1: Engineering [5] graduates and population

Country	Number of graduates in Engineering	Population per engineering graduate
UK	52,798	1,100
South Africa	10,387	4,814
Cameroon	1,619	11,000
Ethiopia	2,235	34,000
Swaziland	6	170,000
Mozambique	162	110,000

Source: UNESCO (*Engineering Report 2010*)

More encouragingly, UNESCO (*Engineering Report 2010*) data found that growth in numbers of engineering students in SSA was well above that of Europe (although starting at a much lower base). Further, the proportion of females enrolled in engineering tertiary education was relatively high in many countries. For example, in the countries in SSA for which data is available for 2006, the proportion of female engineering students ranged between 9% and 43%, compared to 20% in the UK (see Annex A). There are, however, questions over whether the same opportunities are available for women engineering graduates as for their male counterparts (Kehinde & Okoli, 2004 & Maduka 2008).

Perhaps a better measure of capacity than the number of engineering graduates is the number of registered engineers working in a country, as this includes all resident and

[4] Note that 'engineering' is broadly defined to include graduates in manufacturing and construction.
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practising engineers including those from overseas (though it should be noted that in some countries registration is not a legal requirement for engineers). In a 2010 study, UNESCO found that most developed industrialised countries had between 20 and 50 *scientists and engineers* [6] per 10,000 head of population, compared with around 5 in developing countries and 1 in the poorest African countries (UNESCO Engineering Report 2010). This meant that each scientist and engineer would serve between 200 and 500 people in industrialised countries, 2000 in middle income developing countries and 10,000 in African countries. The available data for African countries seemed to support this pattern with each practicing engineer serving 14,000 people in Malawi (ICE/GDC 2002d), approximately 12,000 in Ghana, Zambia and Swaziland, and 3,166 in South Africa (Lawless, 2005).

This begs the question: How many engineers does a country require? To know how many engineers are needed, now or in the future, a detailed estimate of demand is required. UNESCO's Tony Marjoram suggested that the models used for forecasting the need and demand for doctors, which were based on population, should be applied to engineering "so as to examine and improve the health of the nation's technology and infrastructure" (UNESCO Engineering Report 2010 p.313).

As doctors provide a service directly to people, it is sensible to view population levels as approximate indicators of need (although not of demand for doctors, which depends also on ability to pay). However, in the case of engineering, that demand is perhaps more closely related to the needs of the economy. Relating the number of engineers to some measure of current or future economic activity in a country, such as GDP or investment, might be more appropriate in obtaining a rough estimate of demand. It would also be interesting to compare the numbers of engineers in a country with an estimate of the number of engineers required to deliver a country's poverty reduction strategy.

Structural problems

Close examination of the South African situation revealed that the shortage of engineers was most acute in the public sector and in local government. While it was possible that there was an overall shortage of engineers, a further (and quite different) problem seemed to be the unwillingness of graduate engineers to work for local government agencies in remote rural areas. This problem was also noted in Tanzania, where there were opportunities in the rural areas but few willing to avail themselves of them (ICE/GDC 2002a), as well as in Malawi (ICE/GDC 2002d) and in Mozambique where the overall shortage was most critical in the rural areas (ICE/GDC 2002b). Detailed analysis of the pattern of shortages (as evidenced by empty posts) and correct diagnosis of the reasons is clearly important in proposing solutions. In this case improving the wages and other terms and conditions of work for engineers in rural posts might be a more appropriate solution than increasing the number of engineering graduates. The literature also suggested that technicians might have more appropriate skills and be more willing to work in remote areas than engineers *(ibid.)*.

Unemployment

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[6] Unfortunately the data does not distinguish between scientists and engineers or between the various branches of engineering

While the number of graduates may appear small in many African countries, even this small number may not be able to find employment. Unemployment among graduate engineers was noted in Nigeria and Tanzania. Felix Atume, Registrar of the Council for the Regulation of Engineering in Nigeria, reported that there were few employment opportunities and that consequently Nigerian engineers were waiting an average of four years after graduation before getting their first jobs (*UNESCO Engineering Report 2010*).

There are a number of reasons why engineering graduates may be unemployed. One key factor in SSA is likely to be the dominance of foreign companies in most engineering fields. In almost all countries, major infrastructure projects tend to be designed by foreign consultants and constructed by foreign companies, increasingly Chinese. The situation is similar in industry. For example, in 2002 less than 10% of engineers working in the oil and gas industry in Nigeria were Nigerian (*UNESCO Engineering Report 2010*). UNESCO notes that "Such situations have stalled the development of a robust indigenous engineering capacity" (*UNESCO Engineering Report 2010*: p.217).

Quality issues

There are also issues regarding the quality of engineering skills. In South Africa it was not just engineers that were in short supply, but experienced engineers with the appropriate knowledge and skills. The '*Numbers and Needs'* study found a shortage of mid-career staff to carry out production work, so existing mid-career staff were overworked with insufficient time to train junior engineers. These findings were echoed in the SAACE report which noted that, "the most significant problem [reported by engineering consulting firms] was to find suitable, qualified and importantly 'experienced' engineers" (SAACE, 2007: p. 11).

The CIDB and Department of Public Works report *Skills for Infrastructure Delivery in South Africa* (2007: p.4) reached similar conclusions:

> "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."

These findings were supported by a paper examining the status of talent management in the South African consulting civil engineering industry (Oosthuizen and Nienaber, 2010).

In Rwanda, Goodsir et al (2009) found that graduates from the university in Rwanda had strong technical skills but lacked knowledge of project management, economics and planning. They were also weak on report writing and data analysis. In addition the authors found that engineers in the public sector lacked expertise in monitoring and evaluating contracted work and in supervising projects in general.

There were similar findings from Tanzania, where engineers working as consultants in the roads sector were found to lack expertise in business, management and contract administration, with a particular shortage of supervision skills (Hollway, 2000). Professional engineers were considered to be of low standard in that country, and the number of experienced engineers was thought inadequate (ICE/GDC, 2002a).

The low calibre of engineers was also noted in Malawi, along with a shortage of 'competent' engineers (ICE/GDC, 2002d). Graduates in engineering were said to have some theoretical knowledge but to lack practical skills. In Uganda, only 25% of applications to register as an engineer were successful and many were practicing as engineers without being registered (ICE/GDC, 2002c). In Mozambique, the biggest problem (apart from the lack of numbers) was reported to be the lack of managerial skills among local engineers, but technical knowledge may also have been lacking (ICE/GDC, 2002b). In Kenya, the quality of engineering education was said to have deteriorated over the years (ICE/GDC, 2002e).

A further problem noted in Mozambique was that engineers were not always able to see beyond pure engineering solutions to wider social issues. Disagreements were noted between indigenous engineers and donors on the considerations to be taken into account in the design of roads, with local engineers more interested in a 'classic' road rather than the simple access needs of the community. That the locally trained engineers were unable to appreciate the wider benefits (e.g. additional employment, lower cost, community participation) of the simple solution suggested a lack of broader development issues in their education (ICE/GDC, 2002b: p.14). The various quality issues identified here are likely to be linked to the unemployment issues raised above, as engineers without the required skills and experience would find it much harder to secure employment.

4. Causes of skills shortages

This section summarises suggestions in the literature on possible causes of skills shortages. They seem to fall into two main groups. The first group relates to inadequate education and training of engineers, from both a quantitative and qualitative perspective: an insufficient number of engineers are educated to tertiary level, while the poor quality of engineering education and training leaves graduates without the requisite skills. The second group of causes relates to the relative attractiveness of engineering as a profession which affects the ability to recruit students and retain engineers in the sector. These two groups of causes are treated in turn below, followed by a brief look at other, country-specific factors.

Inadequate education and training of engineers

Poor quality of students

Science and engineering education in SSA faces serious challenges at every level; the problem starts in schools. Producing a qualified cadre of engineers requires not only high quality education at tertiary level, but also at primary and secondary levels. Several of the studies made the point that poor educational standards throughout the pipeline resulted in students without the required skills or motivation being accepted onto engineering degrees (Lawless, 2005; CIDB &Department of Public Works, 2007; Alutu and Iruansi, 2008). Poor standards in mathematics were highlighted as particularly troublesome.

In Mozambique the problem was slightly different: here there were simply too few students in secondary education, leading to too few university students in all disciplines.

Competition for students meant that the best might not choose engineering (ICE/GDC, 2002b).

Accepting students without the required knowledge and aptitude inevitably led to a high number of dropouts. Throughput rates at many universities were found to be poor. A study carried out in South Africa, for example, found that the average throughput rate for universities and colleges of technology for 2004 was 14% (CIDB and Department of Public Works, 2007). Explanations included the fact that students found it hard to fund their studies (Goodsir et al, 2009), were poorly prepared for the rigour of university life and were in receipt of inadequate academic support (CIDB and Department of Public Works, 2007). UNESCO (*Engineering Report 2010*: p.215) suggested that students who joined engineering programmes did so only on the strength of their grades rather than from interest or motivation (*UNESCO, Engineering Report 2010*: p.215).

These factors all impacted on the numbers of students graduating with engineering degrees. But evidence of an insufficient number of university *places* was provided only in the case of Rwanda, where both universities providing engineering degrees found their engineering courses oversubscribed (Goodsir et al, 2009).

Poor quality of teaching

The most prominent explanation for poor quality of tertiary education is that it is difficult to recruit and retain high quality academic staff. Academic salaries in SSA are generally very low, and qualified engineers are able to earn more and receive better benefits in the private or public sectors (UNESCO, *Engineering Report 2010*: Goodsir et al, 2009: ICE/GDC, 2002e). The lack of planned career progression was also noted as a factor in Uganda (ICE/GDC, 2002c). It is especially hard to recruit academic staff who have industrial experience, as those that did possess such experience had many alternative options. It was precisely these people who were needed to ensure that academia is keeping up with technological advances, and to equip students with the problem-solving skills required in the workplace (Alutu and Iruansi, 2008). However, actual staff vacancies were only noted in universities in Rwanda (Goodsir et al, 2009).

Several additional explanations for the poor quality of tertiary education were given. First, the limited funding provided to tertiary education institutions resulted in large class sizes, few tutorials, and inadequate facilities and learning materials (UNESCO, *Engineering Report 2010*: Alutu and Iruansi, 2008; Goodsir et al, 2009). In Kenya university equipment was old and library facilities were poor (ICE/GDC, 2002e). Poor facilities were also noted in Mozambique (ICE/GDC, 2002b). This could have been a reason why it was noted in Malawi that courses were too theoretical and lacked practical input (ICE/GDC, 2002d).

The Millennium Project Task Force on Science, Technology and Innovation (Juma and Yee-Chong 2005) summarised the problems in higher education as: "outdated curricula, under motivated faculty [and] poor management" (ibid p.90). Finally, it was argued that in some countries the recent conversion of technical colleges to universities able to offer degree programmes had created a set of sub-standard tertiary education institutions, producing engineers that did not have the skills required in the workplace (Mhilu et al, 2008: Alutu and Iruansi, 2008).

Lack of practical training

Perhaps even more important than the poor quality of classroom teaching was the fact that it was very difficult for students to access work experience opportunities during the course of their studies. This may have been because engineering staff were overstretched and thus unwilling or unable to make time to train and mentor students (UNESCO, *Engineering Report 2010*: Lawless, 2005: SAACE, 2007). But a further factor was that the engineering sector in SSA consisted mainly of small firms that did not have the capacity to provide coherent training (UNESCO, *Engineering Report 2010*), and there was no structured system of workplace training for students (Goodsir et al, 2009). In addition, the training programmes that did exist may have been poor quality because of weak links between academia and industry, so the programmes were not jointly developed and were inadequately overseen (UNESCO, Engineering Report 2010: ICE/GDC, 2002e). The result was that students graduated with some theoretical knowledge but lacked practical skills.

Lack of jobs and training after graduation

After graduating, engineers required ongoing support and training in the workplace. Several authors note that workplace training was inadequate. In South Africa the problem seemed to be that there were not enough highly qualified engineers in the workplace to train junior engineers. Also training and the value of experience tended to be overlooked in the 'lean-mean' business model of the 1990s (Lawless, 2005). An additional argument was that firms did not get the chance to consolidate and grow their capacity through continuity of work. Government-funded training programmes did exist in South Africa, but access was highly bureaucratic and many firms did not have the capacity to access them (CIDB and Department of Public Works, 2007).

In other countries the main problem was actually obtaining a job in a company with experienced engineers. In Tanzania, it was noted that a vicious circle was created with failure to obtain a job meaning failure to gain experience and hence failure to find work. In Uganda and Malawi there was no evidence of graduate training by employers (ICE/GDC, 2002c, 2002d). In Nigeria, it was noted that graduates were not able to get a broad range of experience, as small firms were pushed into repeating the same types of projects in order to be competitive, rather than taking on a range of work (Alutu and Iruansi, 2008).

Attraction and retention of engineers

Several studies from South Africa argued that careers in engineering were not seen as attractive, making it difficult to recruit students to study engineering and/or to retain them in the sector. Reasons given for the unattractiveness of engineering as a career included: long hours and remote locations (CIDB-Department of Public Works, 2007: SAACE, 2007: Lawless, 2005); graduates becoming stuck in production activities due to the shortfall in engineers, and failing to gain the breadth of experience that would enable them to move up the career ladder and gain career satisfaction (Lawless, 2005); poor talent management strategies in firms (for example 43% of private sector firms in South

Africa were found to have no talent management strategy in place) (Oosthuizen and Nienaber, 2010); salaries well below those for graduates in other sectors (e.g. finance and the law) and, in the case of civil engineering, below those of other engineering disciplines (UNESCO, Engineering Report 2010: p. 217: Lawless, 2005). A further factor was that the volume of work in several engineering sectors, particularly civil, was highly variable and depended on government spending levels, major investment projects, etc. When work volumes dipped, trained engineers might have left the industry or emigrated, and might have been be unwilling or unable to return when work levels increased (CIDB-Department of Public Works, 2007).

As a result of all of these factors, many engineering graduates in South Africa chose to take work in alternative sectors such as financial services, where their analytical skills were highly sought-after (CIDB-Department of Public Works, 2007: Hall and Sandelands, 2009). However, when experienced engineers moved from engineering practice into managerial and policymaking positions they were not 'lost' to the profession when their technical training was directly relevant to these positions. This was the case, for example for the regulatory bodies charged with oversight of utilities. Not surprisingly these bodies often experience difficulties in recruiting individuals with the necessary expertise. This was made apparent by the African Infrastructure Country Diagnostic (AICD) study which made an unprecedented effort to collect data on African infrastructure. It concluded that, "[m]ost African regulatory agencies are embryonic, lacking funding and in many cases qualified personnel" (Foster and Briceño-Garmendia 2010).

Little evidence could be found from other countries in SSA on the relative attractiveness of a career in engineering. In countries with no significant industrial base, civil engineering was the branch that predominated.[7] But this section of the industry was dominated by foreign firms, increasingly Chinese, who were often reluctant to employ inexperienced locals. Engineering graduates were therefore likely to be either pushed into the public sector with low salaries and little career progression, or forced to set up their own companies (ICE/GDC, 2002a, 2002e). Either way they had little opportunity to gain experience and improve their skills.

One may conclude that a career in engineering would not appear attractive to potential students. However, in some countries engineers were held in high esteem. Also, it was important to note the existence of a global market for engineers. Labour mobility, combined with the global shortfall of engineers and the attractive conditions in other countries resulted in high levels of emigration amongst trained engineers (UNESCO, Engineering Report 2010: Lawless, 2005). For example, in South Africa in 2002 the number of engineers emigrating annually matched the numbers graduating (Lawless, 2005). This phenomenon also occurred within SSA, with trained engineers from poorer countries on the continent emigrating to countries with higher salaries and better conditions, notably South Africa and Botswana. While the steady flow of engineers to South Africa had partially offset the numbers leaving, it had clearly had a detrimental impact on the countries they had left *(*ibid*)*.

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[7] Anecdotal evidence suggests that those trained overseas in other branches of engineering are often forced on their return to work in areas completely unconnected to their training.

Country-specific factors

There were a number of other factors behind the perceived shortage of experienced engineers in SSA which were specific to individual countries. The literature available offered two particular examples to illustrate this: the cases of South Africa and Mozambique.

South Africa

During the apartheid period from 1948 until 1994, the government invested heavily in engineering and infrastructure. A cadre of highly qualified engineers was developed, but they were almost exclusively white and male. Post-apartheid, equity targets were set in both the public and private sectors. In the public sector, senior white engineers were offered attractive retirement packages, which resulted in a shortage of mid-career professionals in the engineering cadre (ibid). In some cases they were replaced with relatively inexperienced young black engineers (Lawless, 2007), At the same time demand for engineers in the country increased as the African National Congress embarked on a programme of 'Reconstruction and Development', a key element of which was addressing the massive shortfall in infrastructure service provision for the black majority. The shortage of capacity combined with high demand created a bottleneck in the South African engineering sector.

Mozambique

Mozambique has suffered many years of war, starting with the war of independence and, following independence in 1975, war between the different political factions within the country. A peace treaty between the warring factions was signed in 1992.

A significant legacy of the war was the loss of a significant proportion of a generation of experienced engineers between 35 and 55 years old (ICE/GDC,2002b). As might be expected to be the case in several other African countries, war is a major factor behind the migration of skilled engineers, leaving virtually no mentors in the system to assist the younger generation of graduates. As a result, young engineers in Mozambique were placed in very senior positions without the appropriate experience. They had to take major decisions without the management skills to assess or analyse the problem and without a mentor to whom they could turn. In Mozambique the problem was exacerbated by the fact that, while there were a large number of foreign professionals working in the country, companies were restricted to 15% expatriate staff (ICE/GDC, 2002b).

5. Impacts of skills shortages

There was little discussion in the reviewed literature on the impacts of a shortage of engineering expertise. However, some points of consensus emerged, first in relation to infrastructure delivery, and second in relation to economic growth more generally.

Impact on infrastructure delivery

In South Africa it was noted that the shortage of senior engineers meant that they were seriously overworked and had little time to train junior engineers. This situation created a vicious circle: "herein lies a conundrum: it is only possible to develop capacity if there is sufficient capacity to develop this capacity" (Lawless, 2005: p. 3).

Several authors argued that the task of closing Africa's infrastructure gap was made more difficult by the shortage of engineering expertise in the continent. But the impact of inadequate capacity would also depend on where the shortage occured. If posts were unfilled in the rural areas there would be a problem developing rural infrastructure and the consequences would likely be mostly felt by the rural poor. We have seen that this was the situation in several African countries. For example, Lawless (2007) argued that South Africa had insufficient capacity to develop public infrastructure services, and the consequences of the shortfall were unevenly distributed through society:

> "The impact is felt most significantly by the poorest of the poor, who have no alternative but to revert to their previously inadequate services, such as walking long distances for water or paying high prices to water sellers" (Lawless, 2007: p.11)

While the failure to meet the infrastructure needs of the majority of the population was often attributed to lack of capital for investment (and this is clearly a factor), Foster and Briceno-Garmendia (2010) have shown that many countries in SSA were not able to spend the funds they have budgeted for infrastructure investment. They went on to describe how, on average, only three quarters of the capital budgets allocated to infrastructure were actually spent (ibid, p.65). This situation was attributed to various inefficiencies, with inadequate institutional capacity seen as a key contributing factor. The lack of engineering capacity in the public sector to plan, design and oversee the implementation of construction projects, particularly by local government, was also considered likely to play a role.

The shortage of qualified professionals was also found to undermine infrastructure delivery in South Africa in terms of time, cost and quality requirements (CIDB-Department of Public Works, 2007).

Use of foreign expertise

High profile projects, especially those that are donor funded, can import foreign expertise. Hollway (2000) argued that this became more difficult when donors were not involved. Hollway stated that the establishment in Tanzania of a scheme to fund road maintenance locally by a tax on fuel was likely to make hiring of foreign experts much more difficult. As similar road funds had now been set up in many other SSA countries, the problem was expected to be felt more widely (ibid).

However, while importing foreign expertise has benefits, it also presents a number of problems. As UNESCO (*Engineering Report 2010*) argued, foreign expertise was expensive and goals for basic service delivery (including those included in the Millennium Development Goals) would have a greater chance of being met if local, less expensive engineering expertise were available. The need to import expensive foreign skilled labour also had impacts (e.g. in Rwanda) on scarce foreign exchange reserves and led to the export of capital which could otherwise be kept within the country (Goodsir et al, 2009).

Impact on economic growth and industrial development

Another point of consensus was that a shortage of qualified and experienced engineers constrained economic growth. Calestous Juma HonFREng argued that weak infrastructure and a shortage of skilled engineers imposed limitations on Africa's ability to use its abundant natural resources to promote economic growth and to "harness the power of science and innovation to meet development objectives and be competitive in international markets" (Juma, 2006: p. 6). The business community in South Africa was also concerned that engineering skills shortages slowed economic growth (Lawless, 2005).

While it was clear that engineering skills were important for industrial development, it was worth noting that the absence of such skills was not the only factor inhibiting industrial development in SSA. Among many other things, industrial development also requires investment. The lack of evidence in the literature on this point puts a conclusion regarding the relative impact of engineering skills shortages on economic growth beyond the scope of this paper.

6. Strategies to reduce skills shortages

The challenges associated with reducing shortages of experienced engineers were daunting, but proposals for capacity building abound in the literature. Some of the proposed strategies were generic responses to the causes of skills shortages described above. These included: improving training and education from primary through to tertiary education; investing in tertiary education including teachers' salaries, facilities, resources and research; and improving the attractiveness of the industry.

Juma (2006) provided several examples of successful interventions to raise capacity in countries across SSA, including: new institutions of technical higher education in Malawi; reform in Rwanda of existing institutions to bring them into line with national priorities; and upgrade of technical colleges to become full universities in Kenya. But he also stressed the context-dependence of the right solution for each country. If a shortage of graduates was not the problem, then increasing numbers on university courses would not be an appropriate solution.

Many suggestions in the literature were more specific, and several were based on past experience with successful capacity building programmes. Four themes have been identified and are treated in turn as follows: (1) improving tertiary education by increasing links with industry; (2) expanding workplace training; (3) developing other linkages; (4) the role of professional bodies.

Improving tertiary education through improved links with industry

Several of the recommendations for tertiary education stressed the need to enhance collaboration and communication between tertiary education institutions and industry. Juma (2006) highlighted the importance of these links to keep courses relevant and current in rapidly changing technological fields. He proposed the introduction of policies that enabled experienced staff from industry, as well as from government and civil society, to serve as faculty and instructors: a proposal that would also serve to ease the shortage of qualified academic staff. Alutu and Iruansi (2008) made similar recommendations, and pointed to an example of a successful programme at the University of Benin that provided a temporary appointment of one year to qualified practicing engineers who would not have wanted an appointment on a permanent basis.

There were also examples of linkages with particular companies. In a study of successful skills development in other areas of the world, Ansu and Tan (2010) cited the example of a successful Korean tertiary training programme in close collaboration with industry. The Korean government offered to set up a training facility in partnership with the major multinational firm Tata as a strategy to attract Tata to invest. In this way it encouraged investment by easing skills shortages, while also obtaining co-financing and expertise from a major international firm. Other firms followed suit, and eventually these training institutes were brought into the mainstream as tertiary education institutions open to all students. In this way, mainstream, high-quality, industry-responsive tertiary education institutions were developed.

The study recognises that encouraging firms to co-invest in this way requires an attractive enabling environment for investment and business, which is not present in all parts of SSA. However, some examples were provided of similar schemes in SSA, such as the Ghana Industrial Skills Development Centre (GISDC) and an ICT training centre in Mozambique (*ibid.).* Another example was MOZAL, the aluminium producer located near Maputo, initiating a programme to help the engineering faculty of the University of Eduardo Mondlane to raise its standards (ICE/GDC, 2002b). In all these cases the need for competent local engineers was identified by industry, and industry was the catalyst behind the programmes. In the case of GISDC, a donor was also involved.[8]

Ansu and Tan (2010) concluded that countries that responded to the immediate needs of industry while also keeping an eye on the longer-term goal of improving the whole educational system were more likely to have gain a foothold on the technological ladder. Links with industry were seen to be a key factor in successful skills development:

> "Experience in many countries suggests that training institutions which develop close ties with prospective employers and which regularly seek employers' input to develop the curriculum enjoy the best results." (Ansu & Tan, 2010: p. 19)

Workplace Training

Shortfalls in the quality and availability of training continued beyond tertiary education into the workplace. Several studies highlighted the potential training opportunities that could be created by making capacity building activities for local staff a requirement of major public-sector contracts (Goodsir et al, 2009: CIDB-Department of Public Works, 2007: Hall and Sandelands, 2009: Juma, 2006: UNESCO, Engineering Report 2010). The importance of ensuring skills and knowledge transfer in cases where foreign engineers were contracted to carry out the works was emphasised:

> "Foreign workers are an essential element within the mix; the skills shortages in South Africa are so acute... However, in using foreign workers it is vital

[8] Interviews with experienced engineers as part of this project also revealed considerable investment in the training of local engineers by African Barrick Gold in Tanzania

> that engineered into their use is a skills transfer process to local workers."
> (Hall & Sandelands, 2009: p. 218)

Projects with a built-in capacity building programme appeared particularly appropriate in the case of donor projects and other externally funded projects (UNESCO, Engineering Report 2010). In a related point, Juma (2006) argued that workplace training should be linked to infrastructure projects in growing fields in Africa, such as ICT, in order to generate a cadre of engineers qualified to meet current and future needs, and to harness the finance available in fields experiencing high demand.

To combat the shortage of nationals with appropriate levels of experience to train others, Lawless (2005) suggested that the skills and experience of retired professionals could be harnessed. One example of this was the 'ENERGYS' programme, in which 150 students and recent graduates were paired with 50 mostly retired engineers and deployed to local authorities. The programme served to transfer skills and experience, as well as enhancing capacity in local authorities.

The skills and experience of the diaspora could also be a valuable resource in providing high-quality training (Juma, 2006). However, the potential contribution of the diaspora went beyond training, with recommendations that governments should "design programmes and offer incentives that enable expatriates to contribute to national efforts" (Juma, 2006: p. 20). One way in which this could be achieved would be to encourage expatriates to return (Lawless, 2005). Expatriates who remained abroad could also contribute by, for example, developing networks between engineering institutions and training centres in their home country and adopted country.

Finally, workplace training opportunities would be enhanced by the provision of funding opportunities from government. Goodsir et al (2009) provided an example from Rwanda, where the Human Resource Development Agency (HIDA) had established a professional skills development fund which enabled high-flying public sector staff to obtain training at home or abroad.

Developing other linkages

Juma (2006) stressed the importance of the development of high quality research institutions to improve capacity for technological innovation in the engineering sector in SSA (either within or parallel to the university system). He suggested that one approach to resource constraints would be for countries to pool resources to create regional institutions. This clearly implied a role for governments. The technological innovation facilitated by such institutions would generate opportunities for economic growth, and would facilitate the development of African solutions to African challenges, such as the need for affordable, decentralised, renewable energy to meet the dual challenges of climate change and modern energy provision in rural areas.

The role of professional bodies

Enhancing the capacity of professional bodies to support the engineering sector was seen as a key strategy by many of the authors of the reviewed studies. Areas in which professional bodies can support capacity building include: developing and enforcing professional qualifications with commensurate experience for all senior positions

(Lawless, 2005); promoting interactions between government, industry, academia and civil society in their countries, and creating links with engineering academies in other parts of the world (Juma, 2006); recognising tertiary education courses and supporting tertiary institutions in improving the quality of their curricula (Alutu and Iruansi, 2008); supporting and promoting student and graduate training both within industry *(*ibid*)* and through the provision of opportunities for continuous professional development (CPD).

A detailed study of the professional engineering institution in Uganda (the Uganda Institution of Professional Engineers – UIPE) found many problems (Hollway, 1999). These included a very small number of registered engineers due to the inability of graduates to acquire (or demonstrate) experience; a totally inadequate financial resource base, being limited to members' subscriptions; few formal training courses; and very little CPD. Proposals were put forward for strengthening the UIPE, including a plan to develop other sources of income.

Several studies argued that the engineering profession in SSA would also benefit from enhanced collaboration between professional bodies in different countries, both developing and developed, in order to build capacity and learn lessons from successful and unsuccessful interventions (Mhilu et al, 2008: UNESCO, *Engineering Report 2010*, p.315: Juma., 2006).

The impact of 'local content' in the extractive industries

An increasing number of countries in SSA were introducing 'local content' requirements into the regulatory frameworks governing the exploitation of natural resources. These measures were aimed at increasing the proportion of contract value spent on goods and services of domestic origin. As a result, oil, gas and mining companies operating in those countries faced stringent requirements to create jobs, promote enterprise development, and support the development of skills in the workforce (Warner, 2011).

Forward-thinking companies saw the advantages to themselves of this trend in terms of the commercial advantages it offers. This included, for example, staff succession polices that replace expatriate staff with local employees and reductions in the costs of goods and services that could be sourced locally rather than internationally (IPIECA 2011 and IFC 2011). However, there was also some evidence that unrealistic local content requirements (requirements that were beyond the capacity of local industry or the absorptive capacity of particular investments) could result in increased costs, lower government revenues and less competition (Nordas et al, 2003).

Local content requirements were likely to have a positive impact on engineering capacity in SSA as the companies involved sought to 'indigenise' their operations, but some caveats applied. Oil, gas and minerals were non-renewable resources, and workforce development programmes should seek to impart 'transferable skills' that would have application beyond the extractive industries. Where possible oil, gas and mining companies should seek to work through existing education and training institutions so that these institutions would remain national assets after the natural resources had been depleted. And finally, the literature seemed to suggest that local content was most likely to help build local capacity when legislative requirements were realistic and they were taken up by companies who appreciated the strategic advantages of long-term investments in skills development (ibid).

7. Gaps in the literature

Given the scarcity of literature on the topic of capacity building needs in the engineering sector in sub-Saharan Africa, the term 'gaps' in the literature would perhaps be a misnomer. High-quality research in this area, supported by statistical information and other forms of evidence, is urgently needed. Without this information, coherent policy development for capacity building will be extremely challenging. Key areas requiring further research include:

- Improved statistical information on the number of engineering students, graduates and registered engineers with professional qualifications in all countries in SSA. The lack of available data for SSA as a whole is due in large part to lack of reporting capacity. UNESCO (UNESCO Engineering Report 2010) reports that, "In the Sub-Saharan region of Africa, there are still many countries not yet reporting to UNESCO despite the UIS's [UNESCO Institute for Statistics] steadily intensified capacity building efforts." (p.81). An improvement in the quality of data is also required with scientists disaggregated from engineers and the latter subdivided.

- In-depth research on the career profiles of local engineers (e.g. from tracer studies of graduates), current employment status, evidence of shortages (e.g. vacant posts), and current and future projections of the demand for engineers, in individual countries in SSA.
- Research on patterns of, and reasons behind, emigration of engineers at all levels from graduate to senior engineers, both within SSA and with the rest of the world.
- Analysis of policies that have been used to promote engineering capacity and engineering excellence in other parts of the world and the factors leading to their success or failure.

8. Conclusions

The literature review identified little detailed research on the extent and nature of the shortage of engineering skills in the countries of SSA. The evidence that was available indicated the existence of significant shortages of engineers, suggesting that there was an insufficient number of engineers graduating in some countries to fill all the posts that were available. The largest number of unfilled posts seemed to be in government jobs in rural areas.

It was also noted that not all those who did graduate could find employment. This may have been because they were unwilling to work in remote parts of the country. But it could also have been because they didn't have the required skills and experience. Tertiary education was seen as being too theoretical and there was a lack of opportunities for workplace training during and after undergraduate studies. In short, it seemed that the biggest problem in many countries in SSA was a shortage of local engineers with the required level of practical skills. Many of these were skills that were generally acquired and honed through work experience.

The literature suggested that the lack of capacity in the engineering profession created barriers to the achievement of developmental goals, including the Millennium Development Goals. Unfilled posts in local government (especially in rural areas) and/or the employment of unqualified or inexperienced people would certainly have a negative impact on the ability to deliver infrastructure. It was also possible that low capacity in engineering hindered economic growth, for example by preventing countries from harnessing opportunities associated with technological development and exploitation of natural resources.

Proposals for capacity building strategies abounded in the literature, but the challenges were daunting. The engineering sector would require support to meet these challenges. This support would be most effective if it was demand-led, i.e. if the most appropriate approaches were identified by professionals and decision-makers in the engineering sector in SSA. This literature review, combined with the electronic survey and semi-structured interviews, makes a step towards gaining an enhanced understanding of capacity building needs and approaches from the perspective of these groups.

Bibliography

Alutu, O. E & Iruansi, O. (2008) *Education and Development of the Structural Engineer in Nigeria: Some Gaps in the System*. American Society of Civil Engineers Journal of Professional Issues in Engineering Education and Practice, July 2008

Ansu, Y. & . Tan, J-P., (2008) *Skills Development for Economic Growth in Sub-Saharan Africa*. Washington D.C.: World Bank CIDB and Department of Public Works South Africa (2007) Skills for Infrastructure Delivery in South Africa.

Foster, V. and Briceño-Garmendia, C. (2010) *Africa's Infrastructure*, World Bank, Washington.

Goodsir, S., Murray, M. & Jowitt, P. (2009) *Engineering Capability in Rwanda: Final Project Report*. Scottish Institute of Sustainable Technology (SISTech) & UNESCO

Hall, J. & Sandelands, E. (2009) 'Addressing South Africa's engineering skills gaps'. *Education + Training* 51(3)

Hollway, Andrew (2000) *Strengthening the capacity of local consultants in Tanzania: Report and recommendations*

Hollway, Andrew (1999) *Strengthening the Uganda Institution of Professional Engineers (UIPE): Report and recommendations*

ICE/GDC (2002a) *Report on the development of the engineering profession in Tanzania*, Institution of Civil Engineers and Global Development Consultancy

ICE/GDC (2002c) *Report on the development of the engineering profession in Uganda*, Institution of Civil Engineers and Global Development Consultancy

ICE/GDC (2002d) *Report on the development of the engineering profession in Malawi*, Institution of Civil Engineers and Global Development Consultancy

ICE/GDC (2002e) *Report on the development of the engineering profession in Kenya*, Institution of Civil Engineers and Global Development Consultancy International Finance Corporation, A guide to getting started in local procurement [online]. Available at http://www.engineersagainstpoverty.org/_db/_documents/IFC-EAP_Local_Procurement_Guide.pdf. [Accessed 17 February 2012].

IPIECA (2011) *Local content strategy: A guidance document for the oil and gas industry* [online]. Available at http://www.ipieca.org/sites/default/files/publications/Local_Content.pdf. [Accessed 17 February 2012].

Juma, C. (2006) The 2006 Hinton Lecture: *Redesigning African Economies: The Role of Engineering in International Development.* The Royal Academy of Engineering

Juma, C. & Yee-Cheong, Dato Ir Lee. (2005) *Final Report of Task Force 10 on Science, Technology*, United Nations, New York.

Kehinde, J. O. & Okoli, O.G. (2004) 'Professional Women and Career Impediments in the Construction Industry in Nigeria'. *American Society of Civil Engineers Journal of Professional Issues in Engineering Education and Practice*, April 2004

Lawless, A. (2005) *Numbers and Needs: Addressing Imbalances in the Civil Engineering Profession*. South African Institution of Civil Engineering (SAICE)

Lawless, A. (2007) *Numbers and Needs in Local Government: Civil Engineering – the critical profession for service delivery*. South African Institution of Civil Engineering (SAICE)

Maduka, J. (2008) 'Untapped Potential: the role of women engineers in African development'. In Guthrie, P., Juma, C & Sillem, H. *Engineering Change, Towards a sustainable future in the developing world*, Royal Academy of Engineering, London, pp. 41- 46.

Mhilu, C. F., Llemobade, A. A. & Olubambi, P. A. (2008) *Preliminary Study: Engineering Education Evaluation: A Desktop Study, Conceptual Framework and Questionnaire Including Action Points.* New Partnership for African Development (NEPAD)

Nordas, H., Vatne, E & Heum, P., (2003) *The upstream petroleum industry and local industrial development: a comparative study*. SNF Report 2003:8, Institute for Research in Economics and Business Administration, Bergen.

OECD (2007), *Infrastructure to 2030*, OECD, Paris.

Oosthuizen, P. & Nienaber, H. (2010) 'The status of talent management in the South African consulting civil engineering industry in 2008: A survey'. *Journal of the South African Institution of Civil Engineering* 52(2)

SAACE (The South African Association for Consulting Engineers) (2007) *State of the South African Consulting Engineering Profession in South Africa*. South Africa: SAACE

UNESCO (2010) *Engineering: Issues, Challenges and Opportunities for Development*. UNESCO Publishing.

UNESCO(2010) *Science Report*, UNESCO Publishing.

Warner, M. (2011) *Local Content in Procurement*. Greenleaf Publishing, Sheffield.

Watermeyer, Ron and Inba Thumbiran (2009) *Delivering infrastructure at scale in developing countries: numbers or systems*. Paper delivered at the Fourth Built Environment Conference hosted by ASOCSA, Livingston, Zambia.

	Students enrolled in tertiary-level "engineering"* education, 1999-2006, total (persons)								Students graduating in tertiary-level "engineering"* education, 1999-2007, total (persons)							
	1999	2000	2001	2002	2003	2004	2005	2006	1999	2000	2001	2002	2003	2004	2005	2006
Angola	674			1,079					16			15				
Benin									140							
Botswana			352	353		534	603		54		38					
Burkina Faso								1,721								
Burundi				500							34			148		
Cameroon						170		5,906								1,619
Congo				116												
Eritrea	174	372	451			1,286					159	65	185	82		
Ethiopia	5,918	5,892	11,421	9,383	13,625	17,347	16,972	12,967	661	704		1,259	2,197	2,511	2,396	2,235
Gambia										373						
Ghana		8,050	8,972	9,438		8,115				2,124						
Guinea						2,060		1,672								
Kenya		16,435	17,652							4,975						
Lesotho							52			638						
Liberia		2,013														
Madagascar							2,295	2,976			306	102			632	441
Malawi	1,041															
Mauritius	1,909	1,833	1,978	1,847	2,169	2,482	2,971	2,585			387	329	294	734	743	729
Mozambique						2,424	2,788							105	162	
Namibia	305		475		539						10		38			
Nigeria							187									
Sierra Leone		49	80							40						
South Africa		43,35			54,03	62,01	69,02	70,33		5,360		7,079	7,364	8,358	9,003	10,38

		4			8	3	8	9								7
Swaziland	361	327	268			305	225	174		3		8		5	36	6
Togo		256								164						
Uganda	1,356	2,095	3,366			6,332			519	1,077				1,354		
United Rep. of Tanzania	3,406						4,589		957					727		
UK	182,761	178,410	217,529	225,784	177,164	180,656	185,283	191,182	56,069	49,198	57,969	56,315	52,729	48,284	50,704	52,798

*Engineering includes engineering, manufacturing and construction in this definition

Female students enrolled in tertiary-level "engineering"* education, 1999-2006, total (persons)								
	1999	2000	2001	2002	2003	2004	2005	2006
Angola	138							
Benin								
Botswana			78	58		62	74	
Burkina Faso								733
Burundi				43				
Cameroon								
Congo				12				
Eritrea	7	17	22			123		
Ethiopia	516	454	991	765	1077	1932	2433	2134
Gambia								
Ghana		881	962	781		632		
Guinea						141		201
Kenya		2168	2229					

Lesotho							19	
Liberia		499						
Madagascar							424	537
Malawi	174							
Mauritius	433	338	398	390	487	662	841	708
Mozambique						245	278	
Namibia	35		78		97			
Nigeria							21	
Sierra Leone		14	20					
South Africa		7190			13125	15756	16847	18231
Swaziland	25	19	41			48	24	15
Togo		16						
Uganda	741	561	596			1196		
United Rep. of Tanzania	294						468	
UK	31,548	31,550	36,088	35,980	32,921	34,105	35,448	37,881

Female students enrolled in tertiary-level "engineering"* education as a proportion of total students enrolled in tertiary-level "engineering"* education , 1999-2006, total (persons)								
	1999	2000	2001	2002	2003	2004	2005	2006
Angola	20%							
Benin								
Botswana			22%	16%		12%	12%	
Burkina Faso								43%
Burundi				9%				

Cameroon								
Congo				10%				
Eritrea	4%	5%	5%			10%		
Ethiopia	9%	8%	9%	8%	8%	11%	14%	16%
Gambia								
Ghana		11%	11%	8%		8%		
Guinea						7%		12%
Kenya		13%	13%					
Lesotho							37%	
Liberia		25%						
Madagascar							18%	18%
Malawi	17%							
Mauritius	23%	18%	20%	21%	22%	27%	28%	27%
Mozambique						10%	10%	
Namibia	11%		16%		18%			
Nigeria							11%	
Sierra Leone		29%	25%					
South Africa		17%			24%	25%	24%	26%
Swaziland	7%	6%	15%			16%	11%	9%
Togo		6%						
Uganda	55%	27%	18%			19%		
United Rep. of Tanzania	9%						10%	
UK	17%	18%	17%	16%	19%	19%	19%	20%

ANNEX A: Data from UNESCO (2010) report '*Engineering: Issues, Challenges and Opportunities for Development*'