Engineering Council of South Africa and Partners	**Submission to the National Planning Commission on The National Development Plan** **10 March 2012**

Executive Summary

This submission is made by the Engineering Council of South Africa with the support of Engineering Voluntary Associations. The engineering professional community welcomes the National Development Plan and is committed to assisting the National Planning Commission to realise the various proposals.

These comments are pitched at critical high level issues; they do not address matters of detail. Comments focus on the following chapters:

Chapter 3: Economy and Employment
Chapter 4: Economic Infrastructure
Chapter 9: Improving Education, Training and Innovation
Chapter 13: Building a Capable State

The principal theme of our comments is the engineering skills required for realization of the Plan. While this theme is integral to these chapters, it is equally relevant in other areas, for example Chapters 5 to 8.

Our submission regarding engineering skills is summarized as follows:

1. As a country, we have a longstanding deficit of engineering professionals and supporting occupations; this applies to capital projects but more so to ongoing operations and maintenance.
2. The development needs of the country will require greatly increased engineering skills: we signal the need for a significant increase to conceive, design, build and sustainably operate the services and infrastructure needed for quality of life in the future.
3. The shortage of engineering skills must be regarded as a structural problem and addressed as such. We argue that there is a need to increase the number of engineering professionals significantly relative to 2011 as a base.
4. Production of engineering professionals is a pipeline process involving schooling, higher education, post-graduation training in industry (candidacy) to attain the competency for registration and independent practice. An integrated approach is needed.
5. Addressing this structural problem requires concerted action by a group of stakeholders: government, the engineering profession, universities, basic education, employers and Setas.
6. This comment is not an event. We hope that it is the start of a process. The engineering professional community is committed to ongoing engagement with the Commission and with agencies of government charged with implementation of the proposals.

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1. Introduction

The Engineering Council of South Africa (ECSA), together with the Engineering Voluntary Associations listed below that contributed to this submission:

Consulting Engineers South Africa
South African Institution of Civil Engineers
South African Institute of Electrical Engineers
South African Institution of Mechanical Engineers
Mine Professional Associations
and associations that have indicated their support directly to the NPC

welcome the National Development Plan (NDP or the Plan) and make the following submission that it is believed will materially contribute to the fulfillment of the objectives of the Plan.

2. High Level Analysis of the Plan

As engineering practitioners, we are essentially problem solvers, that is, we are concerned with transforming a situation from an initial state to a desired state via a solution path. In the case of the NDP, the initial state is South Africa in 2012. The desired state is encapsulated in the last paragraph of page 136 of the NDP:

> *Closer to 2030, South Africa should be approaching "developed world" status with the quality of life greatly improved across the board, with skilled labour becoming the predominant feature of the labour force, with levels of inequality greatly reduced.*

This objective is elaborated in a number of ambitious targets at various places in the Plan. The Plan examines numerous aspects of the solution path, including challenges, risks, approaches and initiatives. Two phases are identified. First, from 2012 to 2017 the focus is on addressing serious shortcomings including education, skills supply, labour relations, energy, water, municipal services, and research and development linked to industry. Second, from 2018 to 2023, the economic base should be diversified and productivity and innovation should increase.

The Plan is essentially an inventory of the "right things to do" to move toward the desired state, essentially a large number of thrusts which, if the essential ones and a good proportion of the rest succeed, the country will move toward its goal. The Plan identifies a number of initiatives but is, understandably, short on detail. These comments do not attempt to address all aspects of the Plan. Rather, they concentrate on the essential role of engineering in achieving the goals.

2.1. Where Does Engineering Come In?

The earlier chapters of the Plan identify a large number of risks and challenges. These include (in no particular order) climate change, extreme weather, flooding, energy, water supply, sanitation, waste management, electricity supply, a low carbon economy, new energy sources, manufacturing, natural/mineral resources, increased agricultural output, pollution, fuels, and mega projects (e.g. Inga Rapids).

Similarly, a number of sectors and cluster are singled out that will serve as "a platform to launch onto a new growth trajectory". These include agro-industrial, minerals and metals, manufacturing, construction/infrastructure, the green economy and the public service.

A number of chapters identify similar thrusts. Chapter 4, on which we comment in more detail below, deals with economic infrastructure under the headings of energy, linked to coal and alternative sources, electrical generation and distribution, liquid fuels, water resources, transport, and information and communications. Chapter 5 deals with the necessary transition to a low-carbon economy. Chapter 6 refers to expansion of irrigated agriculture and large-scale agriculture. Chapter 8 analyses the transformation of human settlements largely from a spatial planning perspective, underplaying the infrastructure, construction and services that would be needed to implement these plans. Chapter 13 deals with improving the capacity of the state. This capacity must include the conception, planning, contract management and operation of infrastructure projects.

Figure 1: A Profile of Engineering

The **Professional Activity** of Engineering:

- serves the needs of people, economic development and the provision of services to society
- involves the purposeful application of engineering sciences, technology and techniques supported by natural sciences and mathematics
- seeks to produce solutions whose effects are predicted to the greatest degree possible in often uncertain contexts
- has potential adverse consequences and therefore must be carried out:
  - responsibly and ethically,
  - using available resources efficiently and economically,
  - safeguarding health and safety,
  - in an environmentally sound and sustainable way, and
  - managing risks throughout the entire lifecycle of a system, service or product.

Engineering Professionals are characterized by the profiles:

Professional Engineers have a broad, fundamentals-based knowledge of engineering sciences, with depth in specialist areas, together with knowledge of financial, commercial, legal, social and health, safety and environmental matters	**Professional Engineering Technologists** understand the engineering sciences underlying a deep knowledge of specific technologies, together with financial, commercial, legal, social and health, safety and environmental matters	**Professional Engineering Technicians** have working understanding of engineering sciences underlying a set of standard processes and techniques, together with costing, regulatory and health, safety and environmental methodologies
Professional Engineers are primarily concerned with the progress of engineering applications and technology through innovation, creativity and change	**Professional Engineering Technologists** act as exponents of today's engineering technology	**Professional Engineering Technicians** play an essential role in applying proven techniques and procedures to the solution of practical engineering problems

The **Professional Certificated Engineer** is, in general, comparable to the Professional Engineering Technologist but is specially certified in occupational health and safety and in mine or plant operations.

Figure 1 gives a profile of engineering as an activity and profiles of the four categories of engineering professionals. The selection of risks, challenges, sectors and the identified chapters listed above are critically dependent on engineering skills. This is true for the entire lifecycle of the infrastructure, services or product, that is, from conception to planning, design, implementation, operations, ongoing planned maintenance and withdrawal of the service or infrastructure at the end of its lifecycle. The need for enhanced skills is acknowledged but a shortcoming of the Plan is not examining the skills requirements in greater detail in critical focus areas. As an example, Chapter 5 discusses the transition to a low carbon economy but there is only a generalized reference to the required skills (page 181).

The inventory of analyses and initiatives will require significant numbers of natural scientists and engineers. Similar comments apply to other parts of the Plan; only in chapter 13 is the essential role recognized of engineering skills in building a capable state. While the need for appropriate skills is referred to in a number of places, the absolutely critical role of engineering is not adequately recognized in these other contexts. It is worth quoting from Chapter 13, page 380:

> *In fields such as engineering where public safety and related financial risks are involved, it is important that only professionally registered persons are permitted to undertake certain tasks in the implementation of projects.*

The requirements should be extended beyond public health and safety and financial risks. Equally, this statement applies in government and in the private sector. Figure 2 illustrates the factors that render engineering a high-risk activity that needs competent persons for effective performance of work. High-level professionals are also essential to innovation, obtaining effective solutions, environmental protection and sustainability when increasing population places pressure on resources. We also note and are encouraged by the statement:

> *The profession needs to play a strong role in monitoring, regulating and maintaining its professional standards through professional councils and associations, It is essential that this role be protected and promoted.*

Figure 2: When does work require Engineering Professional Skills?

Engineering Professional competence is required to mitigate risks typically occurring in work that:

- Exploits natural resources
- Uses natural and synthetic materials approaching their limits
- Exploits the forces of nature
- Counters and controls the forces of nature
- Involves complexity of system, process or information due to:
    - Having interconnected parts with multiple relationships
    - Exhibiting dynamic behaviour
    - Extending in space and varying over time
    - Having a large scale
- And, in addition, involves risks including:
    - Health, safety of people and the environment
    - Financial and human impact of ineffective solutions

Engineering must therefore be factored into national planning as an essential enabler. This in turn is a problem solving exercise. The present state is that South Africa can be described as "under-engineered" for its present needs. This manifests itself in several ways.

- Insufficient engineering planning, design and operations management is taking place. The prime example is in local government services, which are critically dependent on engineering skills. Municipalities have hollowed out their technical capability, resulting in the so called "service delivery" failures. Elsewhere public infrastructure has not been maintained to the end of its lifecycle. Capital expenditure on replacement of infrastructure at a considerably enhanced cost has been substituted for proper operations and maintenance.
- The number of engineering practitioners available in a country of our size and state of development is low by comparison with other developing economies.

The under-production of engineering graduates and the practice of doing without engineering create the illusion that the shortage of engineering professionals is not severe. We are embarking on the solution path with insufficient engineering skills. The wider solution path for the country depends critically on adequate quantity and quality of engineering personnel (and their proper use).

By a number of measures, albeit imprecise, South Africa needs to increase the number of engineering professionals significantly. In addition, a common understanding of the roles and required mix of engineers, engineering technologists and engineering technicians must be developed. Growth targets must be developed based on an understanding of the needs. These will inevitably be demanding. Until refined targets are developed, parties should look to compound annual increases of registered professionals of at least 10%.

It is not understating the longstanding under-supply of engineering practitioners in South Africa as a *structural problem*, which if not addressed will compromise the country's ability to meet its development goals. The production of engineering professionals is a multi-stage pipeline process and the blockages must be addressed at all levels: school, higher education and post-graduation training (candidacy). The school and higher education aspects are discussed in our comments on chapter 9.

3. Comment on Chapter 3: Economy and Employment

From page 124 onward, the Plan focuses on engineering-intensive activities: agriculture and agro processing, metals and minerals, manufacturing, construction and infrastructure and the green economy. The general comments made above on the critical role of engineering skills are relevant in these areas.

Discussion centres around the research and development (R&D) that must be undertaken to form the basis of increased productivity in existing businesses but, more prominently, in helping to establish new businesses. The need to better align research topics to the strategic development needs of the country is highlighted. We support the view that stable policies and the alleviation of key infrastructure constraints are listed as key enablers of such new enterprises. However, the mechanisms of how R&D must be directed in areas of national interest are not clear, nor are the business incentives other than a sense of "it's good for SA" being articulated.

We feel that the full extent of the different types of R&D is not recognised nor the cost and time implications for the development of important new things. The development part of R&D is critical but is not as fully articulated; it is there that better, cheaper products are made in volume or scale and quickly. Also the role of engineers to make R&D real is perhaps understated and not fully appreciated.

This chapter sketches a large role for the state in the economy. A weakness of this chapter is not addressing how private institutions can be incentivised to participate in implementation. Private institutions inherently have the capability to execute a given amount of work with fewer resources.

The document clearly admits that the capability of municipalities and governmental organisations to actually implement and maintains systems and services has been eroded. Approaches to remedy this

problem focus strongly on the state role. The possibility should be considered that it might be quicker and more efficient if government is willing to incentivise the large capable organisations to actually undertake infrastructure development in support of their investments into SA so that the infrastructure can deliver the economic value.

The document does a good job of indentifying and justifying the areas and sectors where initiatives should focus. However, the requirements or imperatives seem stretched and optimistic and might just be the proverbial bridge too far. Inevitable trade-offs should be based on principled drivers of value: it would have been useful to have these principles listed to give some guidance on how the tough decisions that are referred to a number of times in the Plan will be made.

4. Comment on Chapter 4: Economic Infrastructure

This chapter systematically examines the need for expanded and improved infrastructure to support the economy. The discussion focuses on transport, energy, water resources and information and communication technologies. The chapter is an exploration of problems and options.

The suggestion that economic infrastructure is key to the long-term development of the country and the recognition of the need to adequately plan, finance, implement and maintain is welcomed. A substantial portion of the nation's infrastructure has been allowed to fail prematurely due to inadequate investment and attention being paid to maintenance. This is well documented. The SAICE Report Card 2011 [1] highlights the state of various sectors: water, sanitation, solid waste management, roads, airports, ports, rail, electricity distribution and hospitals and clinics, schools. This report confirms the need for concerted action. Skills requirements and development challenges in Civil Engineering generally and in the municipal sector are analysed in [6] and [7] respectively.

The need to plan and operate large infrastructural systems is identified in the Plan. Some of the complexities are enumerated, for example provision of energy while dealing with carbon intensity and sustainability. Effective procurement of large systems is identified as a critical issue. Present operational failures are described that reinforce the need for "getting it right" in the future. Regulatory difficulties and shortcomings are highlighted.

4.1. Engineering Skills Dimension

This chapter is sound, as far as it goes. However, the critical skills required to achieve the objectives laid down here receive scant attention. While the professional and technical capacity of the state is the subject of Chapter 13, this chapter fails in not identifying skills, and engineering skills in particular, as a critical determinant of whether the infrastructure will be provided and operated effectively. All of the initiatives are engineering intensive. Many are breaking new ground, for example new sources of energy. We mention regulation in particular: it is not possible to regulate an operation that is critically dependent on engineering for its technology, planning and operation without expert engineering input at decision making level.

The capital cost of the envisaged infrastructure is extremely large. The cost of not planning, designing, implementing and operating optimally will add to the costs. The key to effective operations is to have skilled engineering professionals involved in all phases at decision making levels. This indicates that investment in engineering education and training is essential. The education and training

cost is small in relation to the cost of the projects and, more important, the costs of not executing the projects properly. Of utmost importance is the ongoing operations and maintenance of the asset over its lifecycle which requires the requisite technical and managerial skill and experience to prevent costly and unnecessary premature replacement

The significant number of infrastructure initiatives to be tackled reinforces the need to carry out the projects effectively. This requires the whole lifecycle of the project to be in the hands of competent professionals. Our recent past supplies object lessons on how major projects fail. Among other initiatives, the Plan identifies the establishment of electricity distribution entities, the need to improve and maintain municipal electrical infrastructure, the introduction of a system and market operator, and encouragement of independent power producers. The prospects of success are not good unless the lessons are heeded from the failed move to regional electricity distributors. Not only do we need more Professional Engineers but many must be able to work at the technical-political interface.

4.2 Turning Project Goals into Reality

The NPC report makes scant reference to the methodologies needed to realise the ambitious project goals set or inferred in chapter 4 in the areas of energy, resource mining, water, transport, power distribution, municipal delivery, and ICT. There is a well proven strategic reality which requires that a goal can only be achieved if it is based on the necessary and sufficient conditions all working in planned unison. If any necessary condition is absent or is in conflict with others, the goal will not be met. If we focus only on one of these as the *necessary engineering human resources*, a rough idea merges of the additional engineering capacity required to meet the collective goals that have an estimated total installed value (TIV).

Following the recent state of the nation address we assume an infrastructure projection TIV of R800 billion over 3 years. Using proven project management metrics, such a spend goal would require some 7% of its value to be allocated to project management and design including that capacity required by the owners' teams or, in this case, those of the government, the SOEs, provinces and municipalities. Using current average engineering human resource costs projected forward for each of the 3 years on a linear basis only, and assuming an almost step function start to the programme, an owner's team capacity of say one third of this resource, the owners' teams will have to identify, recruit and retain some 6000 to 6500 experienced engineering resources alone to execute this programme load. An assumption made here is that as the current capacity at owner's team level has not been able to meet even its present considerably lower programme budgets, this identified capacity will have to be *added* for the infrastructure TIV to be met.

The current requirements of qualified engineering and project human resources across the board are becoming more difficult to locate and employ. Aging engineering work force, historical lack of investment and focus on engineering candidate training and the emigration of experienced engineering resources through affirmative action pressures are in fact creating a net reduction in the availability of competent engineering resources in the economy. Further, the future feedstock of resources to the profession is at risk with the low maths and science pass rates being accepted at pre-tertiary level.

This metric approach gives some indication of the scale of the engineering human resources required to enable the programme goals outlined in chapter 4 to be initiated let alone met.

The fastest remedy to help to mitigate this position will be for government to radically enable funding of the effective candidate training programmes for graduate engineering resources in industry, SOEs and state services, and to engage the provinces and municipalities in removing unqualified persons acting in engineering roles.

5. General Comment on Professional Engineering Competency Development

At this stage, having examined the role and need for engineering skills (that is engineering practitioners who are competent by way of their education, training and experience) in the economy generally and in infrastructure development in particular, and as a prelude to comment on educational aspects in chapter 9, it is appropriate to make a number of points about the engineering skills lifecycle illustrated in figure 3.

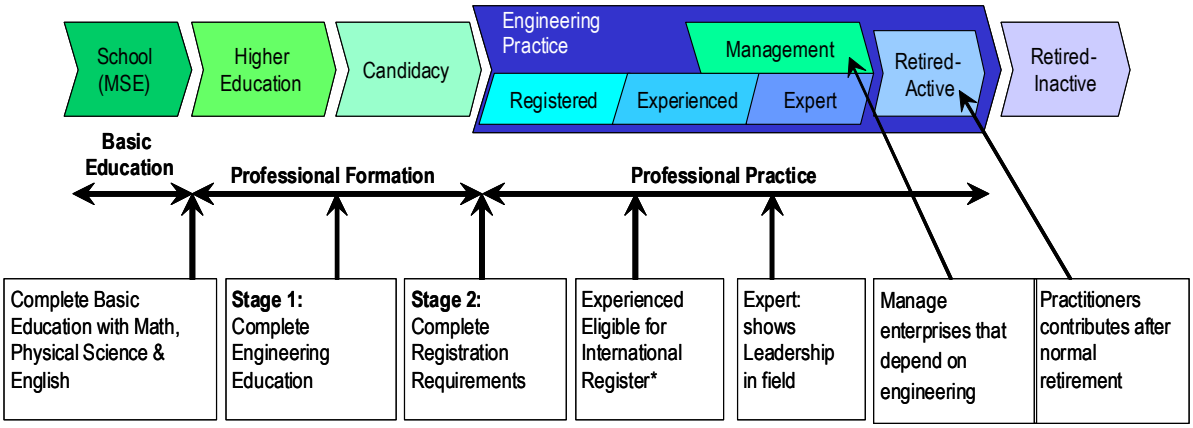

Figure 3: Lifecycle of an engineering professional

The development of engineering professionals is a pipeline process. It has several stages and each stage is dependent on the flow through and quality achieved by the previous stage:

- **Schooling:** Achievement of adequate preparedness in Mathematics, Physical Science and English;
- **Higher Education:** Attainment of a qualification accredited by ECSA for the category of registration shown in Table 1;
- **Candidacy Phase:** Training and gaining experience after graduation to develop the competency required for registration.

Table 1: Educational Requirements for registration in professional categories	
Category of Registration	**Type of Accredited Qualification**
Professional Engineer	BEng/BSc(Eng) – four-year NQF Level 8
Professional Engineering Technologist	BTech – one-year NQF Level 7, having completed a National Diploma
Professional Engineering Technician	National Diploma Three year (including one year experiential training) NQF level 6
Professional Certificated Engineer	Government Certificate of Competency

Blockages exist in the pipeline at all three levels. If the future goals are to be attained, not only will it be necessary to address the blockages but the entire pipeline will have to move to a much larger scale. The first two sectors, schooling and higher education, are discussed in our commentary on Chapter 9 below. Shortcomings in the Candidacy Phase are reviewed next.

At the candidacy level, graduates from the higher education system are not receiving adequate training and experience to develop from graduate competency to professional competency. The minimum period of candidacy is three years. Of the persons registered as Candidate Engineers for more than three years about 10% have attained registration as a Professional Engineer in the last two years. About one-quarter of Candidate Engineers have been registered for six or more years.

An important contributory factor is change that has taken place in all sectors: government, state enterprises and the private sector. Two decades ago, two important conditions prevailed. First, there was a culture of training engineering graduates toward registration. Second, these bodies were adequately staffed with qualified professionals who could plan training programmes, supervise work experience and mentor candidates. In all but a limited number of companies these conditions no longer exist. The de-professionalisation of the civil service and short-term responses to competition in the private sector are contributory factors.

It is appropriate to record that a limited number of employers have exemplary training programmes and also contribute the majority of new registrations. Success factors include:

- Adequate funding;
- Training on structured programmes towards professional registration;
- Training in environments with experienced technical staff, giving direction, mentoring and coaching;
- Effective group work;
- Regular reviews and adjustments to trainee's programmes to ensure progress.

The experience of the majority of trainees is not conducive to attaining registration in a reasonable period.

ECSA has reviewed its registration guidelines to ensure that there is an awareness of requirements and best practice in training. A candidacy phase strategic initiative is underway that seeks to address the poor throughput of the candidacy process. A key aspect of this is unlocking of Skills Levy funding for firms that commit to training and undertake programmes.

6. Comment on Chapter 9: Improving Education, Training and Innovation

6.1 General Comments

Chapter 9 considers all phases of education: pre-school, school, further education and training and higher education. The last two aspects are in many respects a summary of the Green Paper issued by the DHET. This chapter is not concerned with the post graduation (candidacy phase) training.

The following points warrant particular mention from the point of view of ultimately developing an adequate engineering workforce for the country.

6.2 Importance of English in Engineering

On page 266 we note that the importance of proficiency in both the mother tongue and English is stressed in the Plan. English is the most common language of instruction, the language of the engineering literature and the means of local and international communication in engineering. An engineering student or graduate who is not proficient in English is therefore at a disadvantage. This observation is more pertinent given the picture painted in Chapter 7 of South Africa positioned in the World.

6.3 Getting the School System Back on Track

On page 270, two factors largely responsible for the failings of the school system are identified: lack of capacity and patronage. These factors need to be addressed if other aspects of improving the school system are not to be compromised. The proposal on page 282 for getting the dysfunctional schools back on track is critically important.

Other issues originating inside the school system have contribute to its poor performance. For example, the frequent changes in curriculum since 1994 have resulted in teachers, even good teachers, not delivering their best effort to their classes.

6.4. Progress in Higher Education

Two factors are important: the quality of the graduates and the numbers produced.

While academic rankings are always controversial, they are based on output measures of the participating universities. In terms of the Shanghai rankings South Africa looks good. Our experience with BEng-type bachelors degrees in engineering is consonant with the observations made here. There is objective evidence through the ECSA accreditation system and its international calibration through the Washington Accord that the quality of graduates from accredited South African programmes is fit for purpose. The programmes however have high attrition rates.

Table 2: Accredited BEng-type Programmes per million of population

Country	Population	Programmes	Ratio
South Africa	51.5	51	1.0
Japan[1]	125.0	388	3.1
Turkey	76.9	300	3.9
Singapore[2]	5.1	23	4.5
United States	327.2	1854	5.7
Ireland	4.6	30	6.5
Canada	35.1	261	7.4
Malaysia	28.3	211	7.5
New Zealand	4.4	36	8.1
S. Korea	49.2	463	9.4
Australia	23.8	248	10.4
Taiwan	25.0	331	13.2
Hong Kong	7.1	111	15.6
United Kingdom[3]	64.8	1903	29.4

1: Low estimate, not all programmes accredited
2: Low estimate: number of students per programme is large
3: High estimate: cases where two programmes are required in combination

On a population basis, South Africa produces small numbers of graduates, for example 1/30 of the number in South Korea and 1/6 of the number in Australia [5]. Improving throughput is not the complete solution. The student body and the capacity of the universities and universities of technology must increase. (On page 273, it is not clear what is included in the Engineering degree type as the numbers for 2001 and 2009 do not seem to correlate with any particular degree or group of degrees.)

The relatively small size of our engineering higher education sector may also be gauged in terms of the number of engineering programmes per million of population. Table 2 lists the Washington Accord countries with the number of accredited programmes (2011) and their populations (2010). South Africa has the smallest number of BEng-type programmes per million of population.

From Table 2, and by comparison with Malaysia and Turkey in Particular, a reasonable inference would be that a five-fold increase in the number of programmes (or a five-fold increase in the number of graduates) is needed over time.

6.5 School Leavers with Mathematics and Science

Of particular interest to engineering is the target on page 276 (linked to the higher education enty on page 277) for an increase in the number of students eligible to study mathematics and science at university. The following professions would compete for these students: engineering (degrees and diplomas), accountancy, health sciences, mathematical sciences, natural sciences and future mathematics and science teachers. The assumption is that such students would have adequate grades in Mathematics and Physical Science in the NSC. The uncertainty is whether this target is restricted to bachelors programmes or includes diplomas (at universities of technology). The following comment includes consideration of diplomas. It is also uncertain as to whether the Plan refers to the legal minimum for entry to degree studies shown in Table 3 or to a level that reflects reasonable preparedness, that is, well above 50%.

Table 3: Legal minimum entry requirements to degrees and diplomas

Qualification type	Gazetted Minimum Entry requirements
Diploma	An NSC, certified by Umalusi, with *four* recognized subjects with Achievement Rating 3 (40-49%)
Bachelors Degree	An NSC, certified by Umalusi, with *four* subjects from the designated subject list with Achievement Rating 4 (50-59%)

The Plan sets a target of 450 000 school leavers with mathematics and science at a level where they would qualify for entry to university. (The DHET has target of ~300 000 for 2024, somewhat more demanding than the NDP.) Both of these targets are ambitious. For degree and diploma studies, all 450 000 would have to take Mathematics (not Mathematics Literacy) and Physical Science and attain grades that are not only above the legal minimum but that indicate preparedness for the chosen programmes. This should be compared in Table 4 with the base of totals of 290 000 and 220 000 that wrote maths respectively in 2008 and 2011 respectively. In 2011, only 67 514 scored 40% or more in Mathematics and 41 586 were above the legal minimum of 50% required for bachelors degree entry.

This target of 450 000 university-ready matriculants should be seen in the light only 41 586 obtaining 50% (degree legal entry) in 2011. More noteworthy is the decline since 2008 in the number taking Mathematics and the proportionate decrease in those achieving at the higher mark levels. Also, unless

the shape of the mark distribution (and the corresponding distribution of achievement) changes to the more common bell curve, it will be necessary to enroll some 1.6 million in Mathematics to get this output! Thus, while the Plan seeks a large increase at the higher education entry level, the current trend is firmly in the opposite direction.

Given the required five-fold increase in engineering graduates, it seems reasonable to set the target at five times the 2011 value, that is, some 200 000. This is still a stretch target requiring in excess of 9% compound annual growth rate over 18 years.

Table 4. NSC Mathematics performance: 2008-2011

(blanks indicate data not published).

Mark	Year			
Range	2008	2009	2010	2011
0-29	162168	156902	138285	120620
>=30%	136504	133505	124749	104033
>=40%	89788	85356	81374	67154
>=50%	63035			41586
>=60%	42320			
>=70%	25539			
>=80%	12637			
Total	298672	290407	263034	224653

There is also the question of the adequacy of the legal minimum mark as a preparation for engineering degree study. A CDE report [2] highlights the grade inflation that has taken place with the introduction of the NSC and the leveling of Physical Science down to the former Standard Grade. This is borne out by the experience of academics who find that high NSC symbols, even straight As in some cases, are not necessarily indicative of preparedness for degree study.

While setting targets is an important part of any planning process, other key factors must be taken into account. We identify two important considerations

- Expansion of numbers in SET programmes without improvement in performance will be counterproductive. It is therefore insufficient to simply set numerical targets. Quality targets are also needed. For example, the school curriculum, teaching, learning and assessment should be such that levels of achievement are meaningfully graded. For example, 60% achievement in Mathematics, Science and English once was a reasonable prognosis for an engineering degree programme (and the examination system should return to this situation). A common understanding of the outcomes of school education for success in SET careers must clearly be developed.
- The production of engineering professionals is a pipeline process. The performance of the pipeline, by analogy, will depend on the feed stock, the flow conditions and blockages. A perfectly functioning pipeline cannot exceed its inherent capacity, nor can it produce an output that is not already in the pipeline. Output cannot simply be turned on as the 2014/15 targets seem to assume.

If there is progress toward the 200 000 university-entry qualified matriculants, (let alone 450 000), soon the universities will be faced with further increase in demand for places in engineering programmes. It is common cause that the engineering departments in universities are under capacity, particularly in teaching staff, with the present numbers of students [8]. University departments are not in a position to grow at the required rate without major intervention, both externally in the form of increased PQM allocation (backed by real funding increases) and industry sponsorship and, internally, by the universities allocating increased resources over a sustained period. More important, making up the backlog and any increase of student will need more academic staff in engineering department. This is a very difficult task to fulfill with the conditions of service and competition from industry for top engineers.

6.6. Performance Measures in Higher Education

At the top of page 278, a target graduation rate of 25% is set. The problem is the definition of graduation rate. We understand that this is the ratio of the graduates in a particular year divided by the total enrolments (all years of study) in that year. Thus, a four-year programme with even a minute drop-out in each year, cannot achieve 25%. A three-year programme achieving 25% is underperforming. A programme with 100% pass rate in each year and a growing intake likewise cannot achieve 25% throughput. Better cohort-based performance metrics are harder to calculate but do not produce misleading results.

The current measures used setting targets for engineering graduates from universities is flawed. There are in fact three key qualifications listed in Table 1: the four year BEng-type degree providing the educational base for future [professional] engineers, National Diplomas providing the educational base for engineering technicians and the BTech, a one year programme after a National Diploma for educating engineering technologists. Lumping all three qualifications is not a useful statistic as different career paths are involved. Also, it counts a single BTech graduate twice, the other time being when he or she obtained the National Diploma.

6.7 Skills Planning

We make the obvious comment that skills planning is not an exact science and should not be used at too fine a grain of detail. Some thought needs to be given to the consequences of acting on projections that turn out to be wrong. Under-providing is always harmful so this should always be avoided. Is over-provision harmful? In engineering education, through our standards and accreditation system, we keep undergraduate degrees broadly based with a solid core of fundamentals and a strong emphasis on problem solving. Graduates are able to make the transition from their original disciplines to many other fields where they make contributions to the economy. Overprovision of engineering graduates is not harmful provided that they are not so narrowly educated and trained that they cannot make career transitions.

Skills planning in engineering must cover the whole team from research scientist to artisan as illustrated Figure 4.

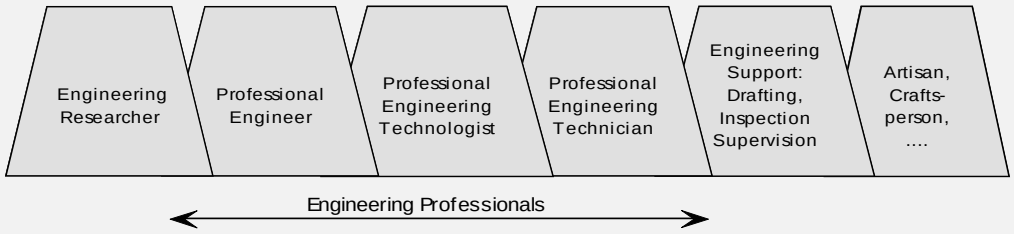

Figure 4: The **Extended Engineering Team** consists of the roles shown

6.8. Building a Strong and Streamlined Quality Assurance and Qualification System

Higher education and further education qualification frameworks have been in an uncertain state and revision proposals have been gazetted recently. The long delay in revising the Higher Education Qualification Framework (HEQF) has been counterproductive. The revised HEQF will meet the needs of engineering if implemented according to the proposal. The FET framework also needs stability and quality implementation of programmes.

We are distressed to see the suggestion that the three quality councils arising out of the NQF Act of 2008 are seen to be in need of reconfiguration. The analysis in the Plan is superficial. We strongly urge that energies be directed at making the present configuration work. Rather solve the right problems. For example, the third paragraph refers to the battle for ownership of Level 5 on the NQF. The simple solution recognises that there will be different types of qualifications at Level 5: occupational qualifications, national vocational certificates and higher certificates designed to give access to higher education, to name a few possibilities. Thereafter, qualifications are quality assured by the appropriate quality council.

The arguments for and against NQF levels are evenly balanced. They may be more compelling at the lower levels of the NQF. However, we have had levels since the inception of the NQF and living with them into the future is probably less disruptive than scrapping them.

6.9. Sequencing the Proposals

Four periods of five years define phases of improvement of the education and training system. We are concerned about the approach to the first five years in that it does not define its measures for "improving the schooling success rate". It is too easy to view school success rate as a statistical problem. Real success however is the lasting effect that schooling has on the learners' future in a variety of areas: university, technical studies, apprenticeships, in the world of work generally and as effective citizens. There are fundamental shortcomings at present. For example, for those going on to SET programmes in universities, the school education does not give adequate preparation. We urge the NPC not to "improve" the schooling system by merely getting more learners with better results. What is important is the outcomes that these results signify. This must be addressed as early in the first phase as possible. If not, the system will produce "more of the same".

6.10. A View on the Throughput Problem

We have indicated that various initiatives in Plan require detailed consideration involving stakeholders. By way of illustration, we show how "improving throughput" in one area, namely four-year engineering degrees requires detailed analysis. When discussing throughput, our assumption is that quality is maintained – and this is the function of the quality assurance system.

In 2011, ECSA commissioned research into the four-year BEng-type degree programmes offered at eight South African universities [4]. The essential motivation is the poor throughput of the programme measured as the proportion of entrants that graduate and the time to graduate. This study identified seven "levers of change" that must be brought to bear on the problem, namely:

i. **Schooling**: improving the 'talent pipeline' from schools into university by, *inter alia*
    a. Engaging government re gaps in the mathematics curriculum
    b. Engaging government about school exit standards and the reliability of school-leaving results
    c. Promoting school outreach and career advice initiatives
ii. **Student selection**: selecting the right students, by
    a. Critically reviewing current selection approaches, in both mainstream engineering and foundational programmes
    b. Investigating how selection processes could better identify student interest, aptitude, insight and problem-solving and analytic abilities
    c. Providing better career advice and student placement mechanisms
    d. Engaging bursary providers to improve student selection and reduce inappropriate 'steering' of student degree choices
iii. **Student support services**: closing the gaps in student support services, both at the institutional level, and from the side of bursary funders and student financial aid agencies, in order to ensure that
    a. Students receive support from the first year of their studies, which is when they need it most
    b. Financial support is available from the commencement of the academic year, so that students do not have to spend the first term or semester worrying about accommodation, books, transport costs etc.
    c. Ensuring that all of the 'hygiene issues' affecting students, such as food, accommodation, transport etc. are comprehensively packaged for each student, and explained to them at commencement of the academic year
    d. Bursaries and student financial aid are available to students on extended as well as flexible mainstream programmes, and that there is flexibility to continue financial support where promising students fail or repeat a course
    e. Ensuring that all institutions, at university, faculty and department level, put in place coherent and comprehensive student support mechanisms which effectively address the social and educational backgrounds of their student intakes
iv. **Curriculum**: ensuring that the engineering curriculum remains relevant and responsive to the demands of professional practice and the needs of business in a changing world, and flexible enough to cater successfully for a diverse student intake by, for example
    a. Undertaking a comprehensive, system-wide review of foundational and extended programmes, aimed at strengthening foundational support to students while informing the development of a more flexible and responsive mainstream curriculum
    b. Monitoring and a critical review of key 'experiments' in curriculum reform, such as those that are under way at the Universities of Pretoria, KwaZulu Natal and Cape Town
    c. Engaging government in order to ensure that the HEQF, HEMIS and funding framework provide funding and recognition for a flexible mainstream curriculum as well as foundational and extended degree programmes

    d. Convening a ‘blue ribbon’ review of the mainstream Bachelors degree, possibly in cooperation with international as well as national bodies; this should consider *inter alia* the policy choices and practical implications pertaining to foundational and extended programmes and a flexible mainstream curriculum

v. **Teaching and Learning**: strengthening the core mission of teaching and learning, *inter alia* by
    a. Holding institutions accountable for teaching and learning outcomes, at key stages in the degree
    b. Encouraging each institution to put in place an effective institutional Teaching and Learning Strategy, as called for by the HEQC
    c. Encouraging the development and recognition of teaching expertise in engineering
    d. Giving national recognition to teaching expertise and research into engineering education, by establishing a system of prestigious grants and awards

vi. **Staffing**: ensuring that mainstream engineering as well as foundational programmes are appropriately staffed, with a sufficient foundation of teaching expertise and professional development support available to lecturers, by
    a. Facilitating the development of a coherent package of measures, including improved funding and salary subventions, to address the staffing crisis in engineering [8]
    b. Reviewing the staffing implications of a flexible mainstream engineering curriculum, alongside options for foundational provision
    c. Supporting postgraduate training and the development of engineering ‘centres of excellence’ aimed at broadening and expanding the academic staff pipeline

vii. **Funding**: ensuring that engineering education is sufficiently well-funded to meet the current and future demand for engineers, maintain quality and standards, and meet the needs of a diverse student intake, by
    a. Engaging government on funding levels for engineering
    b. Engaging government on the higher education funding framework, HEMIS and the HEQF, in order to ensure that foundational, extended and flexible mainstream curricula are recognised and funded through the funding framework
    c. Engaging government with a view to ensuring that the teaching and learning mission of universities is sufficiently recognised and supported
    d. Ensuring that institutional funding of engineering is adequate
    e. Engaging with DHET, NSFAS and bursary funders, to help ensure that students’ financial needs are met in a timeous and effective manner, that students’ career choices are not unduly influenced by the availability of funding, and that bursaries and student financial aid are linked more effectively to student outcomes.

A number of current issues fall under particular levers. For example, the substantial problems with NSFAS funding falls under iii and vii. ECSA is participating in a CHE Currriculum Project under iv(d).

The engineering technology education sector, that is the providers offering BTech degrees and National Diplomas, is clearly in need of a comparable research project but this has not been carried out.

7. Comment on Chapter 13: Building a Capable State

A capable state, together with a vibrant private sector, are essential to the realization of the goals of the National Development Plan. The analysis of the challenge is accurate and we concur with the priority accorded to addressing the deficit of skills and professionalism.

As a preamble to our comments, we find it useful to unpack the notion of *skills*. Often this is used in the sense of being able to do practical things that one has been trained to do. With the emphasis on professional level civil servants, it is more appropriate to think in terms of *competence* and its constituents of knowledge, skills and attitudes, together with the ability to apply these in a practical context. Professional fields have substantial bodies of knowledge. Skills are not merely task-based but include the transferable abilities of analysis, synthesis, evaluation, management. Attitudes include ethical and professional behaviour. The competence of a professional results from education, training and experience.

Our comments on this chapter are organized around certain of the bullets under the heading "What needs to be done" on pages 365 and 366

7.1. Bullet 1 and pp 366-371: Stabilising the political-administrative interface

This section deals with the necessary changes in the administrative and political relationships of the senior civil servants in relation to the Minister. We concur that the model needs revision and that solving this problem is a prerequisite to other steps described later in the chapter for building capable departments, particularly where these rely on professional and technical expertise.

The idea of appointing staff based on merit, with no political interference is most welcome. Continuity is critical. The idea of a Public Service Commission preparing short lists and having a strong, impartial chair is ideal, but is a tall ask. To start the process it may be necessary to head hunt someone who has performed this role effectively in another country and can get the system going and offer the impartiality required.

7.2. Bullet 2 and pp 371-380: Make the public service and local government careers of choice

We make no specific comment here except that this issue is intertwined with the others. For example, success in developing technical and professional skills and providing career-pathing is essential to this objective.

7.3. Bullet 3 and pp 380-385: Develop technical and specialist skills

Our comments are particularly pertinent to the many national and provincial departments and local government activities that are dependent on competent technical and professional practitioners.

Government will require engineering professionals when its activities have characteristics such as the following:

- Protects the physical environment;
- Regulates industries: electricity, telecommunications, energy, railway safety, minerals, …;
- Regulates health and safety in industry and mines;
- Provides large scale housing;
- Manages water resources;

- Provides road infrastructure;
- Provides premises and facilities for its own operations;
- Promotes science and technology;
- Plans infrastructure and services for the future.

Building and recreating technical and managerial capacity must receive the highest priority in order for those responsible to perform the function of " informed client" able to engage constructively with the private sector so as to ensure effective and efficient service delivery, not just the capital works but the ongoing operation and maintenance.

The opening paragraph on page 380 enunciates a number of key principles which can be contextualised as follows:

- Services cannot be delivered without the necessary specialist skills including those of competent technical and professional practitioners;
- This is true in all spheres of government but particularly true for engineering in local government;
- Government entities that contract out functions must have the technical and professional expertise in-house to commission and oversee contracts, and, of paramount importance, to operate and maintain the resulting infrastructure or service, that is they are "informed owners".

The second paragraph on page 380 recounts how the state was once a major trainer and employer of engineers and engineering technicians but this now virtually non-existent. This is linked to the lack of professionals who would supervise and mentor trainees. The adverse effect on the state's ability to contract work out and manage its own operations is all too evident. It is worth making the point that the private sector, while more active in graduate training, with some firms having exemplary training programmes, taken as a whole, is not providing sufficient training opportunities for present requirements. Many firms employ fewer engineering professionals than before, aggravating the training situation.

The problem identified in the third paragraph on page 380, namely that professionals need to be empowered to do their jobs through an appreciation by administrators of the nature and value of engineering, needs major attention. It is not limited to government; many firms in the private sector have a similar lack of understanding of how to extract value from engineering professionals. The need for professional registration for critical tasks is recognized. The specific proposals are to strengthen the state's role in developing technical skills and to provide career paths for technical specialists. An important omission in the strategy described on page 381 is the need for professionals in the various government entities to supervise and mentor trainees (as well as qualified artisans with whom apprentices would work). If a professional structure either does not exist or is not populated with competent professionals, attempts to turn the state into a training ground will be fatally flawed. Attention must once again be devoted to growing the profession by the public sector through the granting of bursaries and other training initiatives to match that currently provided by the private sector.

In addition, it is essential that capacity building initiatives strive to recreate "informed client" status particularly in the field of technical and managerial leadership at appropriate levels with all spheres of government. New procurement models involving support by the private sector can accelerate and enhance this process.

7.4. Bullet 5 and pp 393-399: State-owned Enterprises

The focus of this section is the potential contribution of state-owned enterprises in providing economic and social infrastructure. Brief mention of skills is made on page 397. The point that we make is that most SOEs are critically dependent on engineering skills and, like the state itself and the private sector, SOEs are underskilled. Like the state itself, the SOEs (or their predecessors) were once major training grounds in professional and technical areas and this has diminished. The comments about the need for a proper professional structure, training and career-pathing apply to the SOEs as well.

7.5. Improving Practices in Government Projects

A number of instances have been identified in which processes and practices in government projects can be improved significantly.

Many engineering practitioners who have been involved with infrastructure projects involving government comment that it is not only the absence of professionals than make processes for entering and managing contracts difficult. The systems used by government are often inappropriate. The acquisition of major infrastructure is handled as a standard procurement process as would be the case for normal stores items.

As an interim measure, the capacity of the State can be enhanced by embracing new procurement approaches such as Framework Agreements and PPP's where capacity enhancement is included in the Terms of Reference and is conditional on access to public sector projects. This public/private partnership or service delivery enabler then becomes a win-win for all.

7.5.1. Central Tender Awarding Strategy

The model of awarding large or long-term tenders nationally is welcomed. This team must, however, be composed of experts in the field who carry out the assessments and awards on a professional and administrative basis, above politics or the possibility of corruption. An investigation carried out by SAICE in some 70 municipalities in 2006 showed that only 51% of projects were completed with minor niggles. The rest encountered major problems associated with inadequate scopes of the work, and the selection of inadequate consultants or contractors etc. Many projects had to be abandoned, or were condemned, and much remedial work was required. A national team should not limit itself to overseeing the development of scopes of work and awarding of tenders, but oversight committees will be key to ensuring the designs and project rollouts are taking place at the required pace and to the required standards.

7.5.2. Expanded public works

There is the notion that local labour can be widely harnessed in the construction sector. Whilst this is true, many more opportunities for using local labour should be explored, largely on ongoing maintenance, environmental protection projects, offering home-care for the sick and Aids orphans,

and much more. A selection of local labour opportunities is outlined on pages 295 to 303 in Numbers and Needs in Local Government [7].

7.5.3. Greater delegation

Greater delegation will make a significant difference to service delivery. Far too many levels must sign off on the most mundane of activities. The current structures which have added one or two layers of cadre above the previous levels of technical staff have had the effect of technical staff not being in a position to make decisions, and often not even being in a position to initiate actions which they know to be necessary. Devolving delegation down to the level where delivery must take place should make a significant difference to the pace of service delivery, provided that the budgets are available. This will also contribute to engineering professionals feeling valued, as their professional judgement (a trait on which they are measured at the time of registration) will again be relied upon.

The need to return authority to line management cannot be overemphasized. The purchasing of supplies, employment of technical staff, implementation of systems, disciplining of errant technical staff have all been taken away from technical staff, causing delays, inadequate decisions, and poor service delivery.

7.5.4. Change Management

A major challenge to achieving all of the above will be the level of change management required. Local government employees have slipped into a comfortable pattern of non-delivery hiding behind huge layers of bureaucracy, which will require a major effort to change. The Turnaround approach suggested in 2009 has had little impact, as it was left to each municipality to design its own turnaround strategy. They were thus given licence to continue operating as before! A national team, composed of experienced change managers and experienced local government practitioners will need to develop and have the authority to drive meaningful turnaround strategies in each and every municipality!

7.5.5. Streamlining Reporting

In returning control to line management and those qualified in each post, the need for endless reporting should cease. Reporting and tick-box forms which were issued ad nauseam were designed to assist those who did not know what was required of them to follow processes blindly and report on progress. They have had the effect of undermining the progress of those who were capable, and adding little value to those who were not qualified for their posts.

7.5.6. Reprioritization of Budgets

There is mention of rural municipalities focussing only on essential services and not all the other ‘nice to haves’. This should in fact be the case in all municipalities. Their mandates have been expanded way beyond infrastructure delivery, which is their core business. This has had the effect of diluting the spending on infrastructure. A study carried out for the Gauteng Department of Finance showed that Gauteng local municipalities spent an average of only 12% on infrastructure including capital, operations and maintenance. Some 25 to 30% was spent on staff, another 25 to 30% on bulk purchases, leaving 22 to 27% to be spent on ‘Other’. Having the spend on ‘Other’ at double or more than what is being spent on infrastructure means that reprioritization of activities and spending should become a national imperative. It is noted that the provinces should be playing a major role in health,

education and economic development. LED, running of clinics, and many other public amenities should perhaps be transferred to the provinces to allow municipalities to focus on their core business.

7.5.7. Structuring local government and regionalization

The two tier structures of local and district government have caused much confusion, duplication of effort and animosity. The situation is well explained on page 389. Theoretically the district should have been able to offer support to the region, but in most cases, districts were new structures with limited capacity, and had the effect of holding stronger locals in the districts back. Strong local municipalities per district should be identified and given the funding and responsibility for assisting or incorporating weaker neighbours and then the associated districts could be disbanded. Districts made up of secondary towns and cities should also be disbanded. It is likely that there will then only be a handful of areas where districts will have a meaningful role to play. They should then be strengthened as the regional structure and the local structure should be collapsed into them. This will ultimately mean that we will only have two tiers of local government and not three. Such a notion will not be popular as many political positions will be lost, but it will reduce the confusion and allow the remaining municipalities to focus on service delivery.

8. Conclusion

While these comments focus on the following chapters:

Chapter 3: Economy and Employment
Chapter 4: Economic Infrastructure
Chapter 9: Improving Education, Training and Innovation
Chapter 13: Building a Capable State

and make specific contributions, the single most pressing issue raised in our submission is the critical role of engineering skills in undertaking the various initiatives of the Plan and operating essential services and maintaining the infrastructure. While this theme is integral to the chapters listed, it is equally relevant in other areas, for example Chapters 5 to 8.

Our submission regarding engineering skills is summarized as follows:

1. As a country, we have a longstanding deficit of engineering professionals and supporting occupations; this applies to capital projects but even more so in the ongoing operations and maintenance.
2. The development needs of the country will require greatly increased engineering skills: we signal the need for a significant increase to conceive, design, build and sustainably operate the services and infrastructure needed for quality of life in the future.
3. The shortage of engineering skills must be regarded as a structural problem and addressed as such. We argue that there is a need to increase the number of engineering professionals significantly relative to 2011 as a base.
4. Production of engineering professionals is a pipeline process involving schooling, higher education, post-graduation training in industry (candidacy) to attain the competency for registration and independent practice. An integrated approach is needed.
5. Addressing this structural problem requires concerted action by a group of stakeholders: government, the engineering profession, universities, basic education, employers and Setas.

6. This comment is not an event. We hope that it is the start of a process. The engineering professional community is committed to ongoing engagement with the Commission and with agencies of government charged with implementation of the proposals.

In points 5 and 6 above, we see planning for national development as in inclusive, ongoing process. We therefore propose and commit to an ongoing collective engagement with the Commission and implementing agents of government by a partnership comprising ECSA as the regulatory body, the engineering voluntary associations, universities, employers and Setas.

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