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Design and Engineering Capacity Building for a Sustainable Development of African Economies: The Case of Algeria

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Introduction

Over the past half century, important technologies increasingly have become associated with fields of applied science and engineering. As mentioned in several contributions (Bell 2007, Salter and Gann 2001), design and engineering (D&E) activities constitute what might be considered the 'core' of Science Technology and Innovation (STI) systems in advanced industrial economies. On the other hand, sustainable development rests on proper policies and adequate capabilities in STI. Sustainability can be achieved through the design of products that comply with environmental regulations through proper D&E capabilities. This simple reality has not been clearly perceived in African countries as it has in other parts of the developing world in recent years. This has led gradually to a wide gap

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between advanced and least developed countries (LDC) economies in terms of D&E capabilities. This is perhaps as important as the digital divide, which has been well covered in the literature yet has not attracted much attention from either policymakers or researchers. As Bell put it (2007), there are some indications that global inequalities with respect to the design and engineering component of STI systems in LDCs may be much greater than they are in connection with other components such as R&D.

From a different perspective, R&D and innovation systems have polarised the attention of researchers in LDCs, including in African countries, at the expense of D&E, and it is only recently that D&E has been at the heart of the innovation process. The commodity boom in African economies has brought massive imports of technology in various sectors of industry, broadly defined, as we will see. While the sustainability issue has appeared on the agenda, the learning potential of these international transactions has not always been properly grasped. Yet it would be of enormous importance if proper D&E policies were worked out. This unprecedented window of opportunity for learning via these channels will be lost if no action is taken and the level of awareness remains at its current level.

This chapter examines the current situation of D&E in African industry. To assess the real situation, we looked at a small sample of 20 Algerian firms from both the public and private sectors, including both small and big enterprises from various areas of industry. This exploration enabled us to identify some of the key issues and make some recommendations for policymakers, as well as to suggest some future areas of research. The first section addresses the concepts and tools of D&E, followed by a section that looks briefly at the situation of D&E in Africa. The next section analyses the function of D&E in Algerian industry. Finally, the last section concludes and makes some recommendations.

Concepts and Tools of Design and Engineering (D&E)

The proper definition of D&E is a key issue which needs to be clarified before we engage in an assessment. The design process is principally concerned with how things ought to be. It involves thinking ahead creatively in order to make a technical object that fits the requirements of users or clients. This process of creation often involves developing new combinations of existing technologies. The design problem-solving process evolves through a series of iterative and overlapping phases (stages): from problem identification, through development of different conceptual solutions, to designing a favoured solution and working out the details of the physical artefact (Salter and Gann 2001; Yazdani 1999). It is a recursive practice, a continuous cycle of trial and error focusing on the creation of a physical product and drawing upon the fundamental laws of nature (Constant 2000). In a more precise manner, Bell (2007) defines D&E capabilities as those that transform knowledge from a generally applicable form into increasingly specific and concretised forms. Engineering is the application of scientific knowledge to solving problems in the real world. While science (physics, chemistry, biology, etc.) allows us to gain an understanding of the world and the universe, engineering enables this understanding to come to life through problem-solving, designing and building things. Engineers can be distinguished from other professions by their ability to solve complex problems and implement solutions in cost-effective and practical ways.[1]

The development of the field of engineering has made a significant difference in the scope and the speed with which new knowledge is translated into technical change. Technological capabilities are needed to carry out various kinds of D&E activity, ranging from initial studies to lifelong upgrading (Bell 2007). These activities include a series of successive tasks, namely: studies, concept elaboration, basic design, fabrication, procurement : these are two different steps commissioning start-up and, finally, upgrading. The first step is always a process of 'discovery' as put forward by Haussmann et al. (2005). D&E in an important stage in the innovation process (Bell and Dantas 2009). It is also key to embodying sustainability concerns such as pollution reduction, longer life-cycle and more robust products, eco-efficient energy consumption and so forth. In newly industrialising countries, *adaptive and design capability* are more important than R&D (Intarakumnerd and Virasa 2004).

[1] Source: What is engineering http://whatisengineering.com/ (visited May 2016).

D&E feeds from the R&D sphere and contributes to it through feedback and accumulated experience and experimentation. It also feeds from other spheres, such as technician skills and craft capabilities, and from below the basic operator skills and capabilities (Arnold et al. 2000). This is where most of the DUI (doing, using, interacting) occurs and where the technology use and operations and maintenance provide the opportunity to foresee incremental changes. This is at the firm level. Externally, recent studies suggest that the technology required by the business sector does not come from fundamental or even applied research generated by R&D laboratories, but is generated by D&E activities spawned by interaction with customers, suppliers and competitors. This helps to explain why clusters, competition and linkages with other firms are so important to the technology development process. In addition, the ICT revolution has drastically modified the D&E function (2000). Applications for computer-aided design (CAD) amongst others brought significant advantages in handling general data in D&E by the 1970s. It is now clear that we are moving to a different world with recent technological advancements such as 3D printing. Nonetheless, designers still rely on tacit knowledge and face-to-face exchanges to solve problems and innovate (Bucciarelli 1994; Henderson 1999; D'Adderio 2001; Nightingale 1998; Salter and Gann 2001).

The Situation of D&E in Africa

There is a growing awareness of the importance of design and engineering for African development along with the need to re-industrialise African economies. Calestous Juma's Hinton Lecture to the Royal Academy of Engineering in the UK (Juma 2006) emphasised its role in 'redesigning African economies', focusing heavily on engineering capabilities in connection with infrastructure development, but recognising its much wider significance across other sectors of the economy (cited by Bell 2007:72). Product design and process improvement are important in the emerging innovation systems (EIS) (Djeflat 2011) as a whole in view of the different paths innovation trajectories are likely to take. Industrial policy requires increased productivity based on intensive research into local raw materials, which are better adapted and usually more eco-efficient and more sustainable as inputs to manufacturing, and the acquisition of engineering design and fabrication skills, as well as adaptation of modern technologies and machinery (Emovan 1999).

The ability of a developing country to produce engineering goods is especially important, partly because this requires skills in metal processing and fabrication that are fundamental to manufacturing as a whole. Moreover, the engineering sector functions as the training ground for a wide spectrum of managerial and entrepreneurial skills. It also plays a fundamental role in the assimilation of foreign imported technology. The non-R&D dimensions of technology development may be especially important for the vast majority of enterprises in developing countries that are not engaged in R&D, are far from the technological frontier, and do not require cutting-edge R&D to improve their competitive standing. Achinivu (1999), using the oil sector in Nigeria, distinguishes between rehabilitation engineering, which allows for the possibility of reverse engineering, and classical design engineering. Reverse engineering and reverse design are opportunities to introduce sustainability concerns.

The reality is that D&E suffers from many shortcomings in the African continent. Several studies have analysed D&E in Africa, namely the African technology gap: United Nations Conference on Trade and Development (UNCTAD) (2003), the African Technological Outlook (2011), International Development Research Centre (IDRC) studies on STI in Africa, and others. They all conclude that there is little D&E in Africa and that capital goods and design engineering are almost all foreign due to passive imports of relatively simple-to-use technology with low levels of technical efficiency and sometimes high environmental risks. Industrial engineering as a distinct function has been rather absent in the face of excessive use of turnkey products. Design capabilities are inadequate and often simple testing is called D&E. The lack of local research and design capability is one factor keeping African producers at the bottom of the global value chain (GVC) and outside complex product segments.

These weaknesses have several root causes. The first one is the legacy of import substitution and the effects of structural adjustment programmes (SAPs). Following independence, state-led and elite-managed development strategies targeted industrialisation as a central part of the development agenda in many African countries. The import substitution industrialisation (ISI) model that most African countries adopted in the 1960s and 1970s mobilised investment for domestic industries (nurturing the infant industries). Burgeoning initiatives to develop D&E in industry in some countries included unpacking the technology bundle and disembodying the engineering component. D&E was bought from a different source, with the possibility of outsourcing certain tasks locally. In parallel, several schools and universities introduced engineering training in their syllabuses. The second era started in the early 1980s, when SAPs set batteries of measures such as liberalisation, corrective signals and incentives for the manufacturing sector. This liberalisation process led to industry restructuring and pushed firms to further reduce costs, downsize personnel and cut down on maintenance expenses, an importance source for the development of D&E capabilities. This led to the brutal end of the development of domestic engineering in industry. Since the 1990s, de-industrialisation in several African countries has led to the de-engineering of domestic industry (Djeflat 2014). The collapse of the demand for domestic design and engineering (e.g., for petroleum engineering in Algeria) has resulted in substantial losses of high-level human capital through brain drain, political conflicts, civil war and so on.

Secondly, Africa suffers from the effect of the Dutch disease (for commodity producers), which made it easier to resort to foreign sources for D&E, and the neglect of local competencies both in the industrial sphere and in the training sphere. This contributed to the *de-engineering* phase of African countries and resulted in the loss of interest in the engineering function and the decline in effort made initially by local industry. This is also reflected in the research sphere in engineering and technology in several sub-Saharan African countries. With the exception of Ghana, where the proportion of researchers in engineering reached 19.4 % of the total number of researchers, it does not exceed 8 % in the other countries : Malawi (6 %), Mozambique (4.8 %), Senegal (4.4 %), Tanzania (7.4 %) and Uganda (1.9 %) (NEPAD 2010). It is reflected through the weak demand for D&E consultancy. Out of 138 consultancy bureaus in Algeria, only four are explicitly geared towards engineering consultancy (Ministry of Industry 2011).

The third problem is the foreign-dominated D&E sector in Africa. The failure or lack of regulation in relation to foreign engineering firms has been damaging to local capacity. Local content laws often do not exist, and when they do exist, they are often not appropriately enforced to ensure knowledge transfer from foreign companies to local engineers (Wright 2013). Learning-centred arrangements with international engineering companies supplying design, engineering and project management services for industry and infrastructure projects in Africa are rare.

Fourthly is the major deficit in engineers. As pointed out in earlier studies, the first and most critical skills shortages are in engineering (Lall 1992). Apart from building and construction and civil works, where the rates of locally supplied services appear to be significant, the remaining sectors rely heavily on engineering services supplied by foreign firms. For example, with only 880 men/year (300 engineers and 580 technicians), the local supply of engineering does not exceed 20 % of local needs in Tunisia. The country suffered a deficit of 2,920 men/year, that is, about 4,867 specialists in engineering.

Several obstacles have hindered the development of engineering. Lack of organisation of the sector, limited financial tools designed to cater for the specific needs of the activity, heavy taxation, lack of guarantees and lack of incentives are the most important problems reported. To overcome the weaknesses of local engineering, Tunisian firms resorted to foreign engineering services through two channels. In the first one, local firms hired the services of foreign engineering firms directly, namely in the mechanical and electrical industries and in the fabrication of transport equipment.

The Situation of D&E in Algeria: Empirical Findings

A brief historical analysis shows that the engineering function benefited from an early awareness at the level of policymaking. From the beginning of the industrial strategy, which was part of the first development plan (1967–1969), the steel sector was managed by a group of recent graduates of the top French training institutions, including the Polytechnic of

Paris, the Ecole des Mines and Telecom Paris, where most of the French elite are trained.[2] Two sectors managed by these brilliant engineers, the energy (electricity) sector and the steel sector, were particularly active in the development of D&E capabilities. In the steel sector, a decision was made very early on to open a design office and put local engineers in direct and permanent contact with foreign partners in mixed professional teams. Foreign engineers were compelled to carry out their D&E in these offices. Local engineers had to work with them on all stages through to the realisation of the projects and be involved in the design process. The teams, led by polytechnicians,[3] were comprised of competent, well-trained and dedicated members. Three specialised companies were created to lead the development of effective D&E capabilities; one of these teams, for example, managed to design a complete gas cylinder unit.

All this drive for D&E came to a halt in the late 1970s when the new labour legislation, called the General Statute of Workers (SGT),[4] aligned the salaries of engineers with those of administrative personnel, which reduced the motivation and commitment of the former. Later, in 1980, the government decided to restructure the industrial sector to be dominated by state companies, allegedly to encourage greater efficiency.[5] By restructuring industry, the link between D&E and production was broken, with no possibility of interactive learning. Moreover, the teams of workers who had managed to accumulate D&E know-how throughout the 1970s were dispersed.

Importance of Engineering Personnel The engineering function varies in terms of size from one sector to the other. Its importance is measured in terms of size of personnel, that is, the proportion of engineers in the professional group. The results show that the proportion of engineers is small (5–20 %) compared to the proportion of technicians, who are the

[2] I am indebted for this section to the kind contribution of Mr Omar Lassel, former Head of Engineering at the SNS Company, the major state-owned steel company in the country.

[3] Mohamed Liassine, who was Director General of the steel complex, later became Minister of Industry.

[4] Established by law n° 78–12 of 5 August 1978.

[5] The restructuring of Algerian enterprises was promulgated by the Presidential decree of 4 October 1980.

dominant group (70 %) in some companies in the professional group. In addition, not all engineers are involved in the D&E function. The proportion of engineers involved effectively remains the same, while in some cases, for example electricity, D&E is performed entirely by technicians.

Involvement of Workers in D&E The majority of firms in the sample (60 %) do not involve workers in the D&E function as a result of a lack of capacity to adequately manage workers and the excessive centralisation of decision-making (e.g., in the agricultural machinery sector). This is an indication that the view that D&E is the domain of highly qualified engineers, and eventually technicians, but not of workers still prevails. The DUI process is completely ruled out.

Relationship of D&E and Training Institutions Companies in the sample appear to be fairly open to the training world: 53 % recruit newly graduated engineering students. These are from petrochemicals, pharmaceuticals, energy and building materials sectors. The rest (47 %) who do not recruit their engineers from the training system (agro-food, energy, liquefied natural gas (LNG), mechanical industry, chemical industry and plastics) offer different explanations. These include the existence of their own training facilities (energy sector), internal obstacles such as weak recruitment function (the LNG case), lack of experience and inadequate profile (agricultural equipment) and the quality of engineering graduates, which is considered below standards (in the case of plastics and printing).

Sources of D&E Used by Local Firms To satisfy their D&E needs, local firms use different sources. Nearly half of them (46 %) use their own D&E services which they have developed over the years. These include both public and private companies across all sectors. Bearing in mind the de-industrialisation and de-engineering phenomenon, the score seems fairly high. The second-most important source are the research centres (27 %) used by the agro-food and chemical industries. Algeria has a relatively active research community in both agronomy and biotechnology and hosts the African Agency for Biotechnology (AAB). Local universities come in third (9 %), showing the negligible role they play as a source of D&E services. Their technological trajectory has been different from the trajectory of industry, as we have shown in previous work (Djeflat 1992). Consultancy bureaus also occupy a relatively negligible position (9 %). It is surprising that foreign companies are rarely used (4.5 %), given that many technologies in various development projects are relatively new and sophisticated and require the help of technology suppliers. Finally, own retired personnel (engineers and technicians) are in a weak position (4.5 %), essentially used only by the agricultural equipment sector.

Integration of the D&E Function Within the Organisation The D&E function appears to be well integrated within the organisation in 60 % of cases. Thus, the potential for interactive learning appears relatively high for a number of companies from both the public and the private sector and in various industrial sectors (agricultural equipment, energy, oil refining, petrochemicals, pharmaceuticals, building materials and printing/plastics). In the rest of the sample, D&E is not well accepted. Several reasons are put forward for not accepting the D&E function within the organisation, ranging from the lack of motivation of personnel to the dominant position of the informal sector.

Three reasons given are of particular interest. The first is the preference for foreign sources of D&E: this preference comes also from the consumers and users. For example, farmers tend to prefer imported agricultural machinery, such as tractors and combine harvesters from European and US companies, over that produced locally. The second is the lack of confidence in the concepts and ideas of local personnel within the company. Often, the engineers and technicians who come up with brilliant ideas leading to important improvements in the production process receive no reward. For example, in a public lamp company, one of the technicians managed to improve the productivity rate of the filament production process from 60 % to 120 %, through re-engineering the design of the process. In the face of total ignorance and lack of recognition, he stopped proposing the new incremental changes he had in mind. The third reason given is the significant role played by the informal sector in discouraging the use of local products and services. Competitive products are imported informally and provide tough competition for home-grown products and services. This is the case in the mechanical sector, where spare parts are imported through informal channels.

The Decision-Making Process (Governance) In big state companies, the decision-making process is centralised at head office level, giving little freedom to the production units of the group. This is the case in the LNG sector. The reasons can be attributed to the complexity of the process, where the production units are not considered qualified to interfere with the process. This view, largely held by major industrial public companies, has often annihilated any form of initiative to bring in technological change at the shop floor level, in total ignorance of the doing, using, interacting process taking place at this level.

Conclusions and Recommendations

Based on this analysis, some conclusions can be drawn and recommendations made to promote D&E as a tool for innovation and accelerated growth and development in Africa.

The first conclusion is at policymaking level. D&E cannot be promoted if the level of policymaking awareness of its importance remains low. It rests on three important components: firstly, reinforcement of the importance of the industry option at the level of decision-making in the face of a growing tendency to encourage services and ready-made products and technologies; secondly, the need to encourage productive enterprises in relation to importing ones to reverse the trend of de-industrialisation; and thirdly, the need to encourage, through proper laws and regulations, the development of the D&E function at the enterprise level.

The second conclusion relates to the issue of training and capacity building. Various forms of training are involved: traditional training at the university level (adding more sessions through revision of the curriculum and enhanced internships) and in high technical schools, as well as at the industry level, both in-house regular training and continuous training to update the knowledge and capabilities of both management and employees in the field of D&E. The ICT revolution has made lifelong learning crucial. Several suggestions can be made to improve the recruitment of engineers from the training system and to provide a profile better adapted to the requirements of industry. It relates also to updating the curricula in universities and training centres and regular review of training programmes, training that is better adapted to the specific domains of activity, more specialised training for engineers and technicians, deeper engineering training and project management, continuous training, and more internships. The reinforcement of links with universities and high schools is vitally important. Developing partnerships with foreign firms to use more locally trained engineers and technicians and to train them in D&E needs to be systematically explored in major industrial projects.

The third conclusion is that awareness of the relationship between D&E and the research and development sphere is severely limited. It is important to raise this awareness and to institute policies and strategies to enhance the linkages between research and D&E both at policymaking level and at enterprise level.

The fourth conclusion concerns the creation of more D&E consultancy bureaus in various fields. These are relatively scarce in African countries (only seven bureaus for all the industry needs currently in Algeria) and often companies, particularly the small ones that are unable to import these services, feel the deficit. They are both process-based and product-based.

The fifth conclusion is centred on the role of consumers and users in enhancing D&E through actively encouraging locally designed and engineered products. This role could be even more proactive through open source or open innovation, a proper policy of involving consumers and users in the design of the products.

The sixth conclusion is centred on the need for a strategy to provide access to technology and know-how through imitation. D&E requires in this particular case the development of capabilities to unbundle the technological package through reverse engineering and possibly reverse design, and to incorporate both local design and local inputs. The potential of reverse engineering as a tool for innovation requires specific skills and capacity building. Exploring reverse engineering in a more systematic way, which is within reach of African capabilities in view of the important learning and competence building which has taken place, is crucial. For instance, engineers in South Africa, facing persistent levels of unemployment in the country, are rediscovering the potential of using labour-intensive road construction techniques (Bell 2007).

Finally, existing D&E models may not be appropriate for analysing the evolution of network forms that occur in late industrialising countries, in particular the importance of networks in the development of D&E capabilities, as shown in the example of Petrobras in Brazil (Bell and Dantas 2009). The proposed multi-stage approach to build D&E capabilities (Salter and Gann 2001) mentionned earlier could be applied to African economies both to the industrial and the mineral sector (possibly to the agricultural sector as well).

Further research is needed on why African industry D&E did not evolve to the adaptive capacity and generative stage. Another question is how to involve communities in the entire design process, from problem identification to idea generation, concept evaluation, detailed design, fabrication, and testing and evaluation. Finally, what prospects for South-South collaboration to develop joint D&E capacity in particular in industries where countries have common interests—for example, offshore oil, particular kinds of mining, particular kinds of infrastructure projects and so forth.

References

Achinivu, O. I. (1999) cited by Abubakar Abdullahi. *An impact assessment of science and technology policy on national development of Nigeria*, Phd Thesis – 2008.

Arnold, E., Bell, M., Bessant, J., & Brimble, P. (2000, December). *Enhancing policy and institutional support for industrial technological development in Thailand: The overall policy framework and the development of the industrial innovation system*. Bangkok: NSTDA.

NEPAD 2010 The African Innovation Outlook, African Science, Technology and Innovation Indicators Initiative (ASTII) South Africa, 135 pages.

Bell, M. (2007). *Technological learning and the development of production and innovative capacities in the industry and infrastructure sectors of the least developed countries: What role for ODA?* UNCTAD, background paper n°10.

Bell, M., & Dantas, E. (2009). Latecomer firms and the emergence and development of knowledge networks: The case of Petrobras in Brazil. *Research Policy, 38*, 829–844.

Bucciarelli, L. (1994). *Designing engineers*. Cambridge, MA: The MIT Press.

Constant, E. (2000). Recursive practices and the evolution of technical knowledge. In J. Ziman (Ed.), *Technological innovation as an evolutionary process*. Cambridge: Cambridge University Press.

D'Adderio, L. (2001). Crafting the visual prototype: How firms integrate knowledge and capabilities across organizational boundaries. *Research Policy, 30*, 409–424.

Djeflat, A. (1992). *Technologie et Système Educatif en Algérie*. Alger/Paris: Unesco/CREAD/Medina.

Djeflat, A. (2011). Emerging innovation systems (EIS) and take off: Evidence from the North African countries. *African Journal of Science, Technology, Innovation and Development, 3*(2), 16–45.

Djeflat, A. (2014). *Design & engineering and innovation for African development: Element for a research project*. Paper given at the Globelics 2014 conference – Addis Ababa – Ethiopia.

Emovon, E. U. (1999). National research policy and sustainable development. In P. O. Adeniyi (Ed.), *Research capacity building for sustainable development* (pp. 31–36). Lagos: Unilag Consult.

Hausmann, R., Hwang, J., & Rodrik, D. (2005). *What you export matters: CIC Working paper no. 123*. Cambridge, MA: Centre for International Development, Harvard University.

Henderson, K. (1999). *Online and on paper visual representation, visual culture, and computer graphics in design engineering*. Cambridge: MIT Press.

IDRC The African Technological Outlook. (2011). *IDRC report*. Ottawa, Canada.

Intarakumnerd, P. and Virasa, T. (2004). Government policies and measures in supporting technological capability development of latecomer firms: a tentative taxonomy, *Journal of Technology Innovation, 12*(2), 1–19.

Juma, C. (2006). *Redesigning African economies: The role of engineering in international development*. London: Hinton Lecture, The Royal Academy of Engineering.

Lall, S. (1992). Technological Capabilities and Industrialization, *World Development*, *20*(2), 165–186.

Ministry of Industry (2011) «Catalogues des bureaux d'études et du Consulting» Ministère de l'industrie de la PME et de la Promotion des Investissements, Direction Générale de la vieille stratégique, des études économiques et des statistiques, Document de travail n°26, DGVSEES, Algiers, 138 pages.

Nightingale, P. (1998). A cognitive model of innovation. *Research Policy, 27*(7), 689–709.

Salter, A., & Gann, D. (2001). *Sources for ideas for innovation in engineering design*. Brighton: Science and Technology Policy Research SPRU.

UNCTAD (2003). *Africa's technology gap, Case Studies on Kenya, Ghana, Uganda and Tanzania*, UNCTAD/ITE/IPC/Misc.13, United Nations Publications, July, 123 pages.

Wright, H. (2013). *The engineering capacity needs in sub-Saharan Africa*. London: The Royal Academy of Engineering.

Yazdani, B. (1999). Four models of design definition: Sequential, design centered, concurrent and dynamic. *Journal of Engineering Design, 10*(1), 25–37, Taylor & Francis.