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Research and Development and Innovation: What Role for Design and Engineering in African Economic Development

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Abstract:
While building innovation capabilities is now clearly understood as a key element in the inclusive growth and sustainable development. Amongst the components of innovation dynamics, the issue of design Engineering (D&E) is drawing more and more attention by international organization and a growing corpus of researchers both in the North and in the South. Yet, D&E raise various questions related to the concepts, the tools and the instruments it uses, to the links with R&D and innovation capabilities and finally, to the practices of D&E and the interactive learning at the enterprise level. This article raises the question: what is the state of development of D&E in Africa and Algeria in particular at firm level? To do that a field work involving twenty Algerian firms were surveyed. The findings show that D&E is largely neglected function at firm level as a result of lack of awareness, lack of implication of experienced workers and low practice of reverse engineering.

Keywords: Design and Engineering, Research and Development, capabilities, Innovation, Africa, Algeria

Codes de classification Jel : : 031, O32,

Recherche et Développement et Innovation : Quel Rôle du Design et Engineering dans le développement Africain

Résumé :
Alors que le renforcement des capacités d'innovation est désormais clairement compris comme un élément clé de la croissance inclusive et du développement durable. La question de l'ingénierie de conception (D&E) attire de plus en plus l'attention des organisations internationales et d'un corpus croissant de chercheurs tant au Nord qu'au Sud. Pourtant, le D&E soulève diverses questions liées aux concepts, aux outils et aux instruments qu'il utilise, aux liens avec les capacités de R&D et d'innovation et enfin, aux pratiques de D&E et de l'apprentissage interactif au niveau de l'entreprise. Cet article pose la question de l'état de développement de la D&E en Afrique et en Algérie et notamment au niveau de l'entreprise. Pour ce faire, un travail de terrain impliquant une vingtaine d'entreprises algériennes a été entrepris. Les résultats montrent que la fonction D&E est largement négligée au niveau de l'entreprise en raison du manque de sensibilisation, du manque d'implication des travailleurs expérimentés et de la faible pratique de l'ingénierie inverse.

Mots clés : conception et ingénierie, recherche et développement, capacités, innovation, Afrique, Algérie

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Introduction:

Over the past half century, important technologies increasingly have become associated with fields of applied science or engineering. As mentioned in several contributions, 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 constraints through proper D&E capabilities. This simple reality has not been clearly perceived by African countries as in other parts of the developing world in recent years. This has led gradually to wide gap between advanced and LDC economies concerning D&E capabilities. This is perhaps as important as the digital divide, which is usually well covered in the literature and yet has not attracted much attention neither from policy makers, nor from researchers. As M. 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 polarized the attention of researchers in LDCs including African countries at the expenses of D&E and it is only recently that D&E is 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 later. While the sustainability issue has figured on the agenda, the learning potential of these international transactions has not always been properly grasped. Yet it is enormous if proper D&E policies are worked out. This unprecedented window of opportunity for learning via these channels can be lost if no action is taken and the level of awareness remains at the level it has been. This chapter examines the current situation, of D&E in industry in African industry. To assess the real situation, we have looked at a small sample of twenty (20) Algerian firms both from the public and the private sector and both small and big enterprises from various types of activities. They are both small and big enterprises from various eleven branches of activity: Oil Refining, Gas liquefying, Petrochemicals and Plastics, agro-food, Biotechnology, Electricity, Mechanical industry, Agricultural Equipment, Pharmaceuticals, Building materials, Paper industry and printing. A questionnaire and interviews of management an engineering personnel.

This exploratory study helped harness some of the key issues raised and make some future recommendation for policy-makers and future areas of research. The originality rests on the topic itself. The topic of D&E in an African context has hardly attracted any interest among scholars: it is the first time that the issue of D&E is looked at as a tool for innovation and sustainable development. Section 1 addresses the concepts and tools of D&E. Section 2 looks briefly at the situation of D&E in Africa. Section 3 analyses the D&E function in the Algerian industry. Finally, section five concludes and makes some recommendations.

1 - Concepts and tools of design and Engineering (D&E):

The issues in defining properly D&E is a key issue, which needs clarification before we engage in the 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 fitting 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 phase (stages): from problem identification, through development of different conceptual solutions, to designing a favored solution and working out 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 project and drawing upon the fundamental laws of nature (Constant, 2000). In more precise manner, Bell (2007) D&E capabilities as those capabilities for transforming knowledge from generally applicable form in increasingly specific and concretized 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 engineering field has made a significant difference in the scope and the speed with which, new knowledge translates in technical change. Technological capabilities are needed to carry out various kinds of D&E activity running from initial studies to lifelong upgrading (Bell 2007). These activities include a series of successive task namely: studies – concept elaboration – basic design – detailed engineering – fabrication procurement construction – commissioning star--up and finally upgrading. The first step is always a process of "discovery" as put forward by Haussmann and Rodrik (2005). D&E in an important stage in the innovation process (Bell and Dantas 2009). It is also key in embodying sustainability concerns such as pollution reduction, longer life cycle and more robust products, eco-efficient energy consumption etc. In newly industrializing countries, *adaptive and design capability* are more important than R&D (P. Intarakumnerd[a] and T. Virasa). D&E feeds from the R&D sphere and contributes to it through feedback and accumulated experience and experimentation. It also feeds from the other spheres such as technician's skills and craft capabilities and from below the basic operators' skills and capabilities. This is where most of the DUI (doing, using, and interacting) is occurring and where the technology use and operations and maintenance gives 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 to that, the ICT revolution has drastically modified the D&E function (Gann, 2000). Applications for computer-aided-design (CAD) amongst others brought significant advantages in handling general data in the D&E by the seventies. It is clear now that we are moving to a different world with the recent technological progress such as the 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)

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

Table (1) : Typology of engineering and sectors of activity

Type of engineering	**Contents**
Civil engineering	Civil engineering; Architecture engineering; Construction engineering, Municipal and structural engineering; Transport engineering.
Electrical engineering, Electronic engineering, Information engineering	Electrical and electronic engineering; Robotics and automatic control; Automation and control systems; Communication engineering and systems; telecommunications; Computer hardware and architecture
Mechanical engineering	Mechanical engineering; Applied mechanics; Thermodynamics; Aerospace engineering; Nuclear related engineering; Audio engineering, reliability analysis.
Chemical engineering	Chemical engineering (plants, products); Chemical process engineering;
Materials engineering	Materials engineering; Ceramics; Coating and films; cements, Composites ; Paper and wood; textiles; including synthetic dyes, colors, fibers
Medical engineering	Medical engineering
Environmental engineering	Environmental and geological engineering, geotechnics; Petroleum engineering, (fuel, oils),Energy and fuels; Remote sensing; Mining and mineral processing; Marine engineering, sea vessels; Ocean engineering.

Source: Unesco Institute of Statistics – Unesco - 2014

2. – 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-industrialize African economies. Calestous Juma's Hinton Lecture to the Royal Academy of Engineering in the UK (Juma, 2006) emphasizes its role in 'redesigning African economies" – focusing heavily on engineering capabilities in connection with infrastructure development, but recognizing 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 path innovation trajectories are likely to take.

Industrial policy requires increased productivity based on intensive research into local raw materials, which are more adapted, usually eco-efficient, and more sustainable as input to manufacturing and the acquisition of engineering design, 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 opens the possibility of reverse engineering, and classical design engineering.

Reverse engineering and reverse design are opportunities to introduce sustainability concerns. The reality shows that D&E suffers several shortcomings in the African continent. Several studies have come with some results of the D&E in Africa namely the Africa technological Gap: UNTACD (2003), The African technological outlook (2011) IDRC studies on STI in Africa etc. They all conclude that there is little D&E and that capital goods and design engineering are almost all foreign in the face of passive imports of relatively simple use technics 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. There are several roots of these weaknesses. *The first one* is the legacy of import substitution and the effects of Structural Adjustment Programs (SAP). Following independence, State-led and elite managed development strategies targeted industrialization a central part of the development agenda in many African countries. Import substitution industrialization (ISI) model that most African countries adopted in the 1960s and 1970s mobilized investment for domestic industries (nurture the infant industry).

Burgeoning initiatives to develop D&E in industry in some countries included unpacking the technology bundle and disembodying the engineering component. D&E are bought from a different source with the possibility to outsource locally certain tasks. In parallel, several schools and university introduced the engineering training in their syllabuses. The second era started in the early 1980s, when SAP set batteries of measures such as liberalization, corrective signals and incentives to the manufacturing sector. This liberalization process led to industry restructuring and pushing firms to reducing costs further, downsizing personnel and cutting down on maintenance expenses an importance source for the development of D&E capabilities. This led to the brutal end to develop domestic engineering in industry.

Since the 1990's, de-industrialization leading to the de-engineering of domestic industry in several African countries has been on (Djeflat 2014). Several causes can be mentioned:

The first one is he collapse of the demand for domestic design and Engineering *(e.g.*, in Algeria for Petroleum engineering) led to substantial loss of high-level human capital through brain drain, political conflicts and civil war etc.

The second one is 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 in both the industrial sphere and 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 of the de 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%) (ASTII 2013). 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 one 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-centered arrangements with international engineering companies supplying design, engineering and project management services for industry and infrastructure projects in Africa are rare.

-*The fourth one if the major deficit in engineers*: As pointed out in earlier studies, the first and most critical skills shortages are in engineering skills (Lall; 1992, Bell, 2006). Apart from building, construction, and civil works, where the rates of locally supplied services, appear to be significant, the rest of the sectors relies heavily on engineering services supplied by foreign firms. For example, with only 880 man/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 2920 man/year i.e. about 4867 specialists in engineering.

Several obstacles hampered 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 directly the services of foreign engineering firms namely in the mechanical and electrical industries and in the fabrication of transport equipment.

3 - The situation of D&E in Algeria

A brief historical perspective shows that the engineering function benefited from an early awareness at the level of policy-making. Right at the beginning of the industrial strategy, which was part of the first development plan (1967-1969), the steel industrial sector was managed by a group of managers freshly graduated from top French top training institutions such as *Polytechnic of Paris*, the *Ecole des Mine*s and

Telecom Paris, where most of the French elite come from[2]. Two sectors managed by these brilliant engineers, the Energy (electricity) sector and the steel sector, were particularly active in development of D&E capabilities. In the steel sector, very early, a decision was made to open a design office and put local engineer in direct and permanent contact with foreign partners in mixed professional teams.

Foreign engineers were compelled to do their D&E in these offices. Local engineers had to work with them on all stages until the realization of the projects and get involved in the design process. The team led by polytechnicians[3] were made of competent, well-trained and dedicated members. Three specialized companies were created leading the development of effective D&E capabilities: one of them managed for example to design a complete gas cylinder unit. All this drive for D&E came to a halt, when in the late seventies; the new labor legislation called the General Statute of Workers (SGT)[4] aligned the salaries of engineers with those of administrative personnel, which reduced their motivation and commitment.

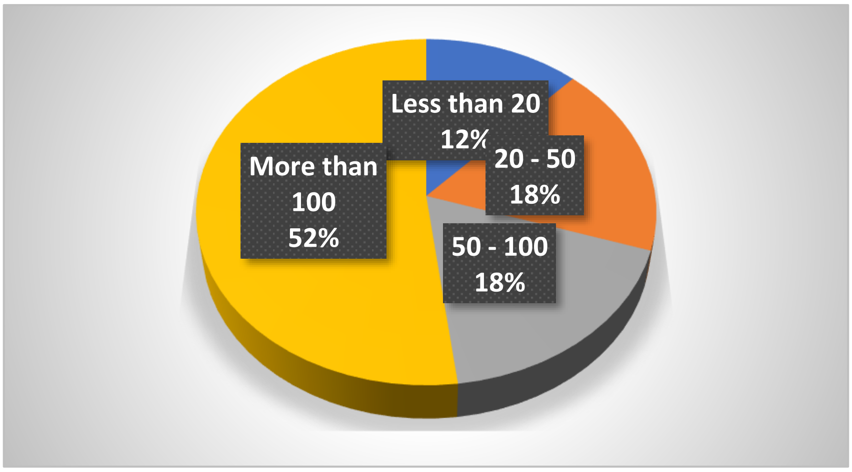
Later, in 1980, the Government decided to restructure the industrial sector dominated by State companies for allegedly higher efficiency[5]. By restructuring industry, the link between D&E and production was broken with no possibility of interactive learning. Moreover, the teams of workers, who managed to accumulate D&E know-how throughout the seventies, were dispersed.

4. Results of the field work

4.1. Structure of the sample:

While most companies in the sample are SMEs, 70% tend to be large to medium SMES (more than 50 employees), 52% have more than one hundred employees: they belong mostly to the public, with one exception only. Medium size (lower end) tends to of the same proportion as medium size upper end (18%). Only a small proportion have less than 20 employees. This is an indication that the engineering function is more concentrated in medium to large size SMEs.

Figure (1) Size of companies in the sample

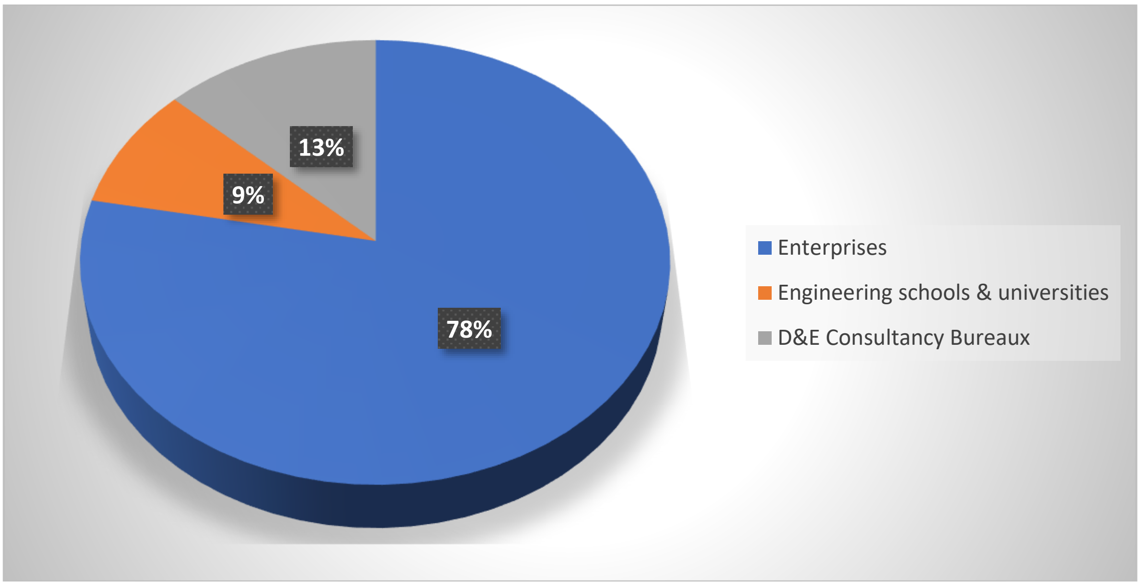


Source : Field work

[2] I am indebted for this section on 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 became Minister of Industry later
[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.

Regarding the type of D&E, most of the engineering practiced is basic engineering (72%) particularly civil engineering for the installation of the infrastructures of the equipments. It also includes access roads, bridges , towers and the necessary facilities within the manufacturing facilities. Algeria is now nearly sel sufficient regarding civil engineering. Its major deficit is with Detailed engineering, where it is still highly dependant on the supply of foreign companies
Similarly Design which an essential function of Innovation remains relatively in the sample. Only 8% of the companies practice Design.

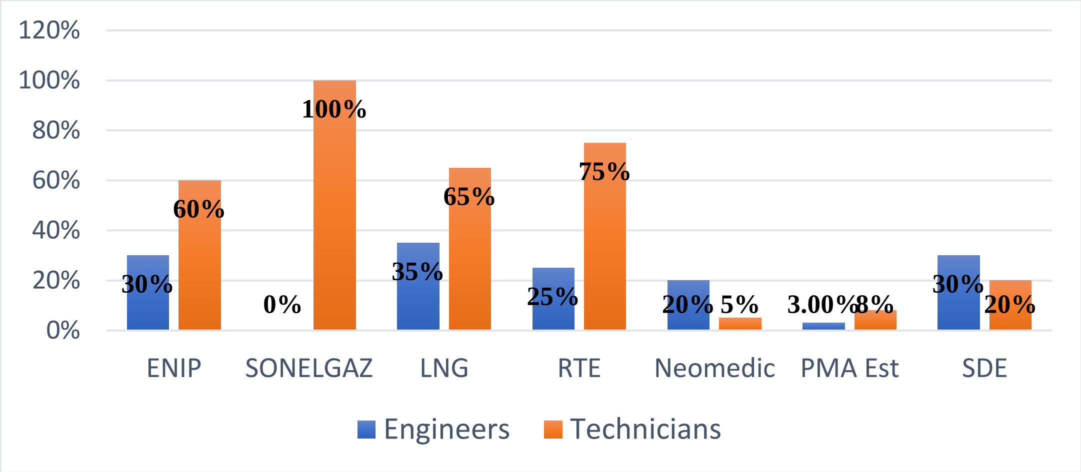
Figure (2) The types of Design and Engineering praticed and their importance in the sample



Source : Field work

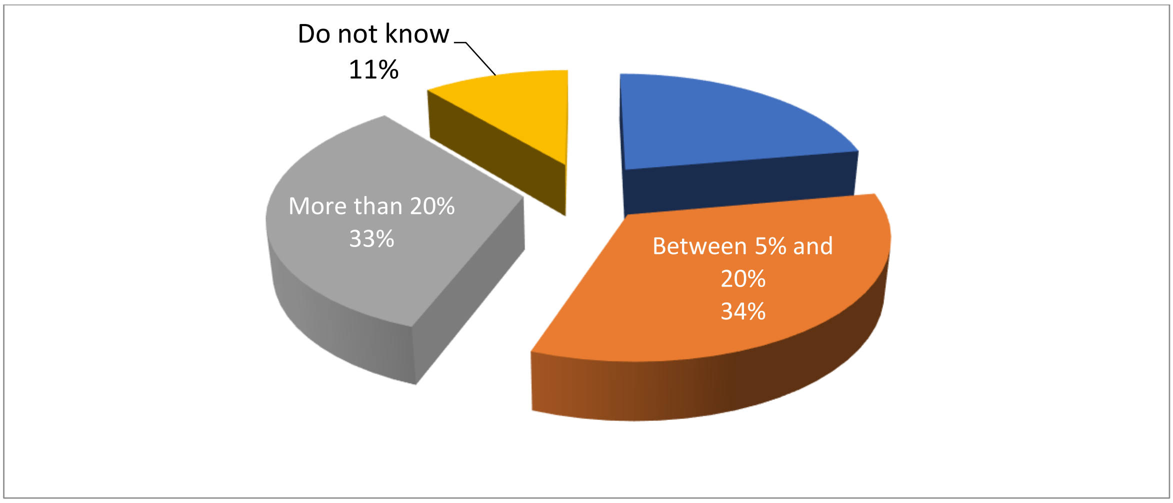
4.2. Importance of the engineering personnel*:* The engineering function varies in terms of size from one sector to the other. Its importance is measured in terms of size of personnel i.e. the proportion of engineers in the professional group. The results show the proportion of engineers is minor (between 3% to 20%) compared to the proportion of technicians who are the dominant group in some companies (100%) in the professional group e.g., electricity, D&E is totally performed by technicians (Figure 3). In addition, not all engineers are involved in the D&E function. The proportion of engineers involved effectively remains low, only 33% spend more than 20% of their time doing effectively engineering (Figure

Figure (3) Nombre d'ingénieurs et techniciens dans les études et l'engineering



Source : Field work

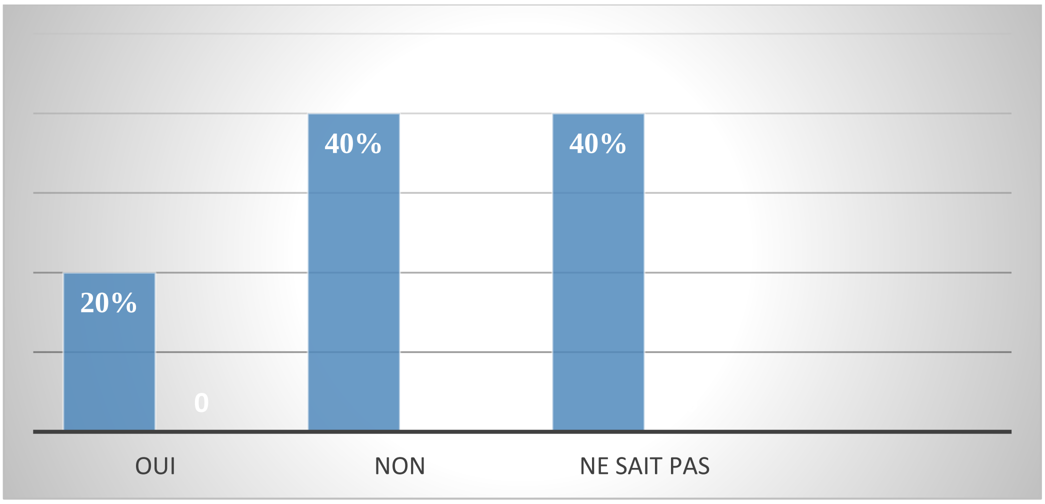
Figure (4) : The Proportion of engineers practising effectively the engineering function



Source : Field work

4.3. Involvement of the workers in D&E: The majority of firms in the sample (80%) reckon not involving workers in the D&E function as a result the incapacity of the firm to manage adequately workers implication and excessive centralization of decision making (e.g., in the agricultural machinery sector). This is an indication that the view strongly held is that D&E is the domain of highly qualified engineers and eventually technicians but not the workers still prevails. The DUI is completely ruled out.

Figure (5) : Involvement of the workers in the D&E function



Source : Field work

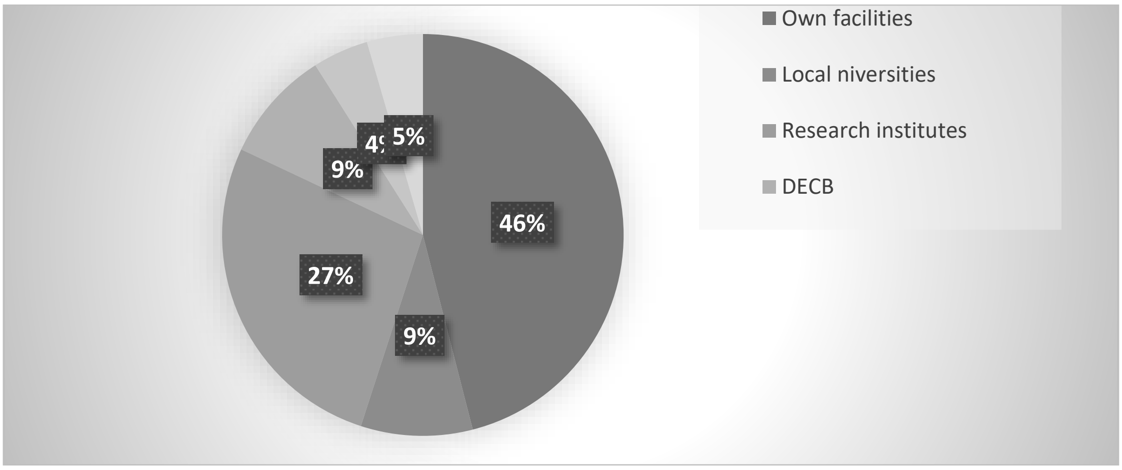
4.4. Relationship of D&E with training institutions*:*

This is a crucial question, which is in the heart of the research. It determines the extent to which DE and R&D are integrated. There are four types of situations. The first category of companies has both DE and R&D integrated in the same department. They are a minority (13%) in the sample. In the case of agricultural equipment, they were initially different services, but were then reunited in the same department called the "Methods" department. In the case of ceramics, the R&D department includes the engineering services. The second category of companies have close relationships between DE and R&D department and services. They constitute the majority and account for 47% of companies in the sample. When looking closely at these companies, they are mostly old well-established companies from the public sector: energy, Gas liquefaction, petrochemicals, agricultural equipment, oil refining. Only one company is from the private sector in the pharmaceuticals sector (Neomedic). The third category of companies have distant relationship between the two functions (13%). They are from the agro-food (poultry), printing, and plastics (Apvatec). Finally, a last category has no R&D department or services. In other words, they are not involved in formal research. They are all private companies et represent 27% of the answers to this question: Agro-food (Metidji), Agriculture (AIA), mechanical industries (GGM, plastics and printing (TRAPACT).

4.5. The sources of D&E used by local firms:

To satisfy their needs of D&E, local firms use different sources. Nearly half of them (46%) use their own de services, which they developed over the years: they are both public and private companies. They belong to all sectors as shown by the figures. Bearing in mind the des-industrialization and de-engineering phenomenon, the score seems fairly high. The second most important source are research centers (27%) used by the agro food and the chemical industry. Algeria has had a relatively active research activity in both agronomy and biotechnology. It hosts the African Agency for Biotechnology (AAB). Local universities come in the third position (9%) showing the negligible role-played they play as a source of D&E services. Its technological trajectory has been different and divergent from the trajectory of industry, as we have shown in previous work (Djeflat, 1992). Consultancy, bureaus take on a relatively negligible position (9%). Surprisingly, foreign companies are rarely used (4.5%) knowing that many technologies in various development projects are relatively new and sophisticated and require the help of technology sup pliers. Finally, own retired personnel (engineers and technicians) are in a weak position (4.5%) used essentially by the agricultural equipment sector.

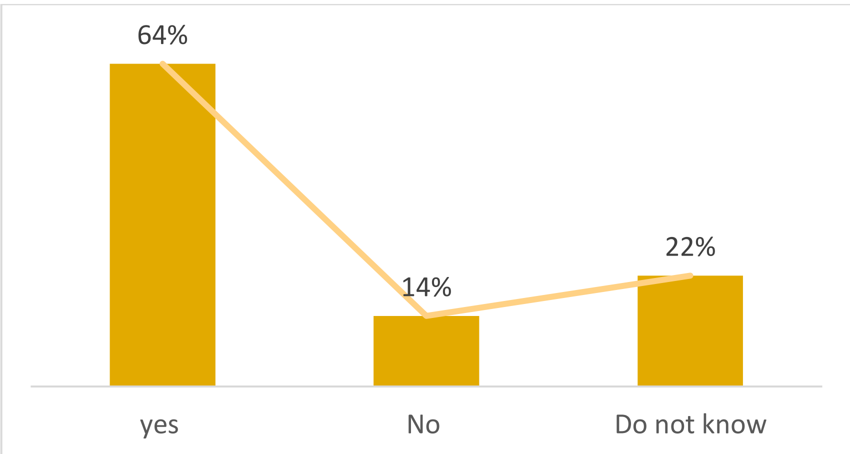
Figure (6) : The sources of D&E used



Source : Field work

4.6. Integration of the D&E function within the organization: The D&E function appears to be well integrated within the organization (in 64% of the cases). Thus, the potential for interactive learning appears relatively high for a number of companies from both the public and the private sector . In the public sector, they are from agricultural equipment, energy, oil refining and petrochemicals. In the private sector, they belong to pharmaceuticals, building materials and printing/plastics. Quite surprisingly in two process industries (petrochemicals and gas liquefaction), the DE function does seem to be easily accepted. In 27% of the cases, the answer is not clear. Several reasons are put forward for not accepting the DE function within the organization: they are formulated essentially by the LNG and the CMA companies. They range from the lack of motivation of personnel to the dominant position of the informal sector. Often, the engineers and technicians who have come with brilliant ideas leading to important improvements in the production process had no rewards. 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 new incremental changes he had in mind.

Figure (7) : Acceptation of the Engineering function



Source : Field work

Several reasons are put forward for not accepting the D&E function within the organization: They range from the lack of motivation of personnel to the dominant position of the informal sector. Three main reasons draw the attention in particular.

The first one is the preference for foreign source of D&E: this preference come also from the consumers and users. For example, farmers tend to prefer imported agricultural machinery such as tractors and combined harvester from European and US companies than the ones produced locally.

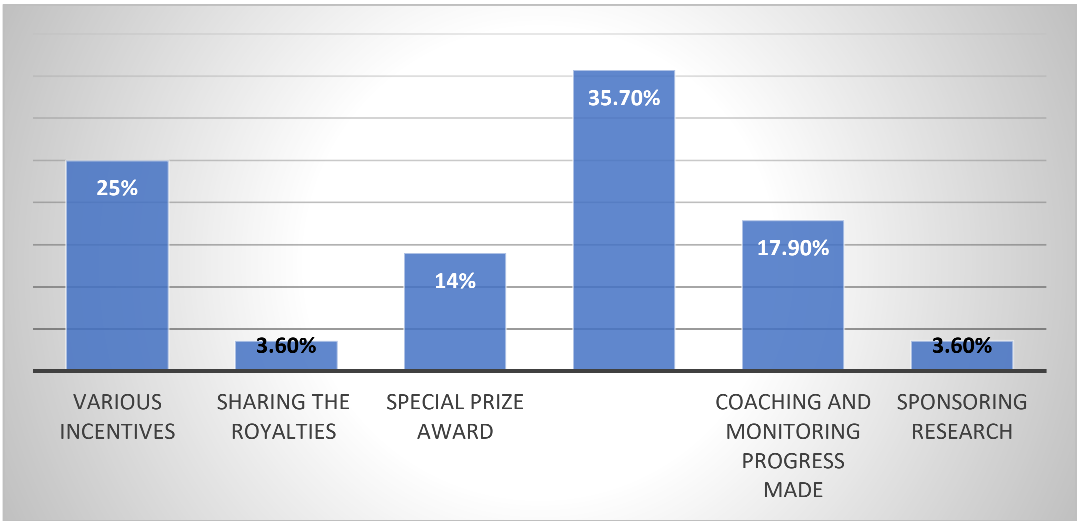
The second one is the lack of confidence for concepts and ideas from local personnel within the company. Often, the engineers and technicians who come with brilliant ideas leading to important improvements in the production process have no rewards for that. For example, in a public lamp company, one 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 new incremental changes he had in mind.

The third one is the informal sector, which played a significant role in discouraging the use of local products and services. Competitive products are imported informally and constitute a tough competition for homegrown products and services. This is the case of the mechanical sector where the imports of spare parts are through informal channels.

4.4.1. Incentives used by local firms

Incentives used to motivate the DE personnel constitute a key element in the motivation of local engineering personnel. They are even more important, when it comes of the DE function, which require high degree of commitment and creativity. In our case, local firms appear to use various incentives to motivate the DE personnel. They can be listed in the decreasing order of importance. Giving additional and complementary training, to update the knowledge comes in the first place (36%) It is put forward by Oravio, Metidji, GNL, RTE, Neomedic, SDE, CMA, GGM, APVATEC. In the third position comes Coaching and monitoring progress made (18%) put forward by Metidji, GNL, Neomedic, CMA and CERAMICS. Special prize award comes in the fourth position (14%) put forward by Oravio, GNL, APVATEC, and CERAMICS. Sharing royalties and sponsoring research come in the last position (3.6%) (Oravio and Sonelgaz) showing that the links between DE and innovation is still tenuous and not well perceived by local companies. Finally, various incentives are used but are not specified in the answers.

Figure (8) : The incentives system used to involve the D&E personnel



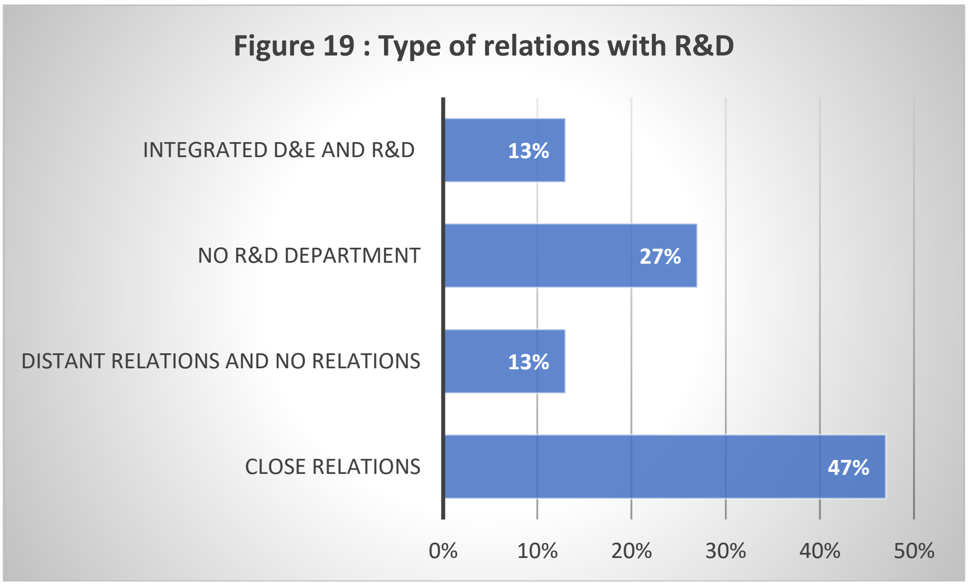
Source : Field work

4.7. Relationship between DE services and the R&D department.

This is a crucial question, which is in the heart of the research. It determines the extent to which DE and R&D are integrated. There are four types of situations. The first category of companies has both DE and R&D integrated in the same department. This is a minority (13%) in the sample. In the case of agricultural equipment, they were initially different services, but were then reunited in the same department called the "Methods" department. In the case of ceramics, the R&D department includes the engineering services. The second category of companies have close relationships between DE and R&D department and services. They constitute the majority and account for 47% of companies in the sample. When looking closely at these companies, they are mostly old well-established companies from the public sector: energy, Gas liquefaction, petrochemicals, agricultural equipment, oil refining. Only one company is from the private sector in the pharmaceuticals sector (Neomedic). The third category of companies have distant relationship between the two functions (13%). They are from the agro-food (poultry), printing, and plastics (Apvatec). Finally, a last category has no R&D department or services. In other words, they are not involved in formal research. They are all private companies et represent 27% of the answers to this question: Agro-food (Metidji), Agriculture (AIA), mechanical industries (GGM, plastics and printing (TRAPACT).

The interaction between R&D and Engineering department are very frequent or frequent in 80% of the cases where the relation is seen as close or fairly close relationship, showing that an intense interactive learning is taking place. This occurs when a new product or process is being launched mostly in the public sector and in the process industry (energy, LNG, and oil refining). However, product industry is also represented by the agricultural equipment and the pharmaceuticals sector. In some other companies, they are rare in the petrochemicals and in biotechnology.

Figure (9) :The interaction between R&D and Engineering department



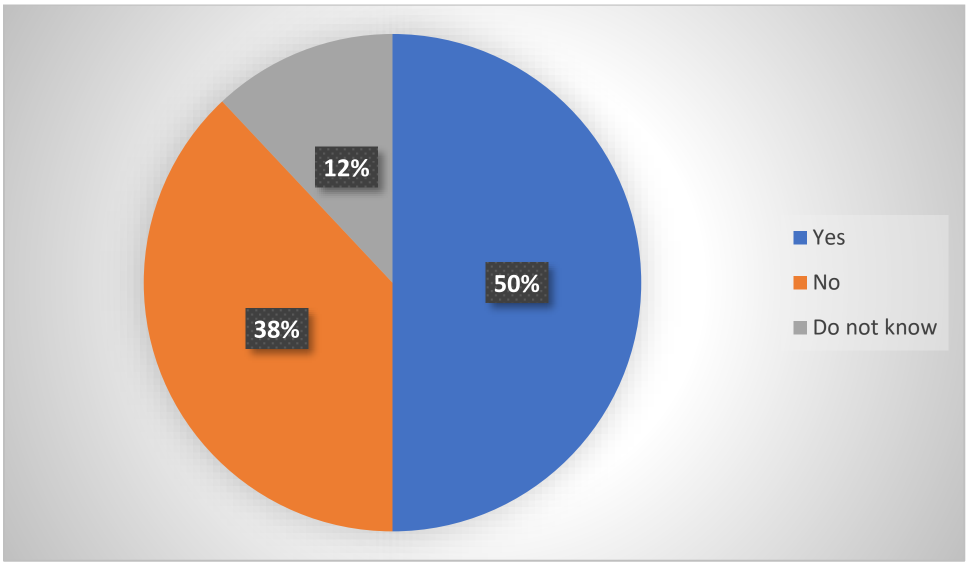
Source : Field work

4.6. The decision-making process (governance): In big Sate companies, the decision-making process is centralized at head-office giving little freedom to the production units of the group. This is the case of the LNG sector. The reasons can be attributed to the complexity of the process where the production units are not considered capable of interfering with the process. This view largely held by major industrial public companies has often annihilated any form of initiatives to bring in technological change at the shop floor level, in total ignorance of the doing, using, interacting (DUI) process, which takes place at this level.

4.7. Funding of the DE function

The funding remains an important issue, in the same way R&D is in the enterprises from the South. Policy –makers may not be aware of its importance. Often this function is part of the technological package and is hardly taken out the bundle in the public sector companies. It is financed thus by the budget devoted to the project. Similar attitudes can be found in the private, whose main concern is to get the production unit working rapidly and realize the expected return on investment. Not surprisingly, 50% of the companies find no difficulty in funding DE. A close look at the list shows that 63% (5 out of the eight) are from the public sector and are funded from public money. The rest (47%) are private companies and often the funding is from private money bearing in mind that the difficulty in finding loans for this type of activity from the bank can be quite high. The public company are from the energy, the agricultural equipment, and the oil refining sectors. Private companies are from pharmaceuticals, building materials (ceramics), printing, and plastics. Nonetheless, 50% the companies find it difficult to fund the DE function. It is interesting to note that half of these companies are from the public sector and should normally find it easy to fund DE. They are from petrochemicals, gas liquefaction, and oil refining sectors. The other half are from the private sector, namely from agro food, mechanical industry and printing. The reasons for not funding easily the DE are diverse: they include mostly the reluctance of Banks to finance this kind of activity in addition to some bureaucratic problems experienced in the hierarchy.

Figure (10): Difficulties in financing Design and Engineering



Source : Field work

4.8. The acceptance of foreign partners

The acceptance of foreign partners is another important issue. The role of foreign partners does not seem to be always well perceived. One of the reasons is that not many companies have a significant experience with foreign partners as we have seen earlier. It is seen mostly in terms of transferring technology to workers. CMA has had extensive experience with foreign partners in the area of DE. It sees this role as multi-faceted. It took the form of on-the-job training and training abroad in the facilities of the foreign partner. Other companies showed a certain mistrust in the training provided by foreign partners: they argue that foreign partners do not provide all the necessary know-how in order to prolong the dependency of the client. Finally, others prefer the training by domestic institutions to foreign ones like in the Ceramics Company.

5. Conclusions and recommendations

At the outset of this analysis, some conclusions can be drawn, and recommendations made to promote D&E as a tool for innovation and African accelerated growth and development.

The First one is at policy-making level. D&E cannot be promoted if the level of policy-making awareness on its importance remains low. It rests on three important components: first, the reinforcement of the importance of the industry option at the level of decision-making in the face of growing tendency to encourage services and ready-made products and technologies. Second, the need to encourage productive enterprises in relation to importing ones to reverse the trend of des-industrialization. Third, 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 training and capacity building issue. Various forms of training are involved : traditional training at the university level (adding more sessions through the revision of the curriculum and enhanced internships) and high technical schools, at also at the industry level both in house regular training and continuous training to update knowledge and capabilities of both the management and employees in the field of D&E. The ICT revolution has made the lifelong learning crucial. Several suggestions can be made to improve the recruitment of engineers from the training system and have a more adapted profile to the requirements of industry. It relates also to the update of curricula in universities and training centers and regular review of training programs, more adapted training to the specific domains of activity and more specialized training for engineers and technicians and deeper engineering training and project management. Continuous training and more internship. The reinforcement of the links with the university 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 need to be systematically explored in major industrial projects.

The third one is the low degree of awareness of the relationship between D&E and the research and development sphere. There is a clear deficit in the comprehension of the relation between R&D and D&E. It is important to raise this awareness and to put up policies and strategies to enhance the linkages between research and D&E both at policy-making level and at enterprise level.

The fourth one concerns the creation of more de consultancy bureaus in various fields of D&E. There are relatively scarce in African countries currently (seven bureaus only for all the industry needs currently in Algeria) and often companies, particularly the small one who cannot import these services, feel the deficit. They are both process-based and product-based.

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

The sixth one is centered on the strategy to be adopted to have access to technology and know-how through imitation. D&E requires in this particular case the development of capabilities to unbundle the technological package trough reverse engineering, possibly reverse design, and incorporate both local design and local inputs. The prospects of reverse engineering as a tool for innovation require specific skills and capacity building. Exploring in a more systematical way the reverse engineering, which is within the grip 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 persisting levels of unemployment in the country, are rediscovering the potential for using labor-intensive road construction techniques (Bell 2007).

Finally, existing D&E models may not be appropriate for analyzing the evolution of network forms that occur in late industrializing countries: in particular, the importance of networks in the development of D&E capabilities as shown the example of Petrobras in Brazil (Bell and Dantas 2009). The proposed multi-stage and multi-level capabilities in a co-evolutionary process applied to African economies: to industry and to the mineral sector (possibly to the agricultural sector).
Further research is needed on the issue why African industry D&E did not evolve to the adaptive capacity and generative stage. How to involve communities in the entire design process, from problem identification to idea generation, concept evaluation, detailed design, fabrication, and testing and evaluation. 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 project, and so forth.

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