The Development and Utilization of Science and Technology in Productive Sectors: Case of Developing Africa

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Résumé: *Le développement socio-économique est étroitement lié à l'exploitation et la transformation par la société du système naturel par la société. La science et la technologie sont des instruments puissants dans l'utilisation de la nature et la promotion du développement. A ce titre, elles constituent une dimension incontournable du processus de développement. Cependant en Afrique même si l'importance de la science et de la technologie est unanimement reconnue, elle n'est pas traduite dans les actes. La science et la technologie demeurent un domaine réservé aux intellectuels et font rarement l'objet d'une prise en compte véritable ou d'une allocation de ressources suffisantes. Les obstacles à la promotion de la science et de la technologie doivent être recherchés dans les rapports fonctionnels entre les institutions (gouvernements ou secteurs privés) l'infrastructure scientifique et technologique et les secteurs productifs. Les pays en développement devraient accorder une plus grande attention à la manière dont les résultats de la recherche scientifique sont utilisés dans les secteurs productifs pour satisfaire les besoins fondamentaux de la population au lieu de faire de la recherche pour des raisons purement théoriques et académiques.*

Introduction

Socioeconomic development depends on the transformation and exploitation of the natural surroundings by society. One of the most powerful instruments for the utilization of nature and for fostering development is science and technology (S&T). Nowadays, the major global issues which are at the interface of social and natural systems are characterized by a strong scientific and technological dimension. Science and technology are not only fascinating to engineers and academicians, but government policy-makers and private entrepreneurs have also fallen under the spell of the new scientific and technological developments. However, while there was a professed realization of the importance to develop both science and technology and

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environmental protection in various developing countries, that realization was seldom translated into action. Both issues were abundantly intellectualized but scarcely, if ever, internalized or matched by adequate allocation of resources to this area in the past decade. The few developing countries that have invested in endogenous capacity building in science and technology have succeeded in improving the living conditions of their peoples, particularly in East Asia, but such success stories are few in other developing countries, particularly in Africa.

The application of science and technology to development in developing countries in general and in Africa in particular, is often seen as one of several alternatives, weighted in terms of labour and capital intensity, available to produce a given product in a more efficient and economic way. It was never recognized as an all-embracing process that affects people's cultural traits and attitudes as well as public institutions and the natural environment. These links that make humans and nature more responsive to sustainable development were marginalized for the following reasons:

a) Science and technology have been construed as high level scientific research and manpower training, while the application of available, off-the-shelf, science and technology has been ignored. This has greatly affected the funding of science and technology;

b) There has been little effort to apply research results and findings to local development, and no mechanism has been created for the commercialization of research results;

c) The private sector, the stake-holders like the bankers, entrepreneurs, consumers, etc. have not been involved in the drawing up of a science and technology programme in their activities; like do many private enterprises in developed countries which devoted much funds in research and development (R&D);

d) Scientific and technological research and development priorities are not always in line with the country's priority needs. Much attention was devoted to other inputs (labour and capital);

e) Scientific and technical education at primary, secondary and tertiary levels were not in tune with the requirements of modern S&T development, and a scientific culture was not present;

f) Incentives to scientific and technological personnel, and to developers, users, and entrepreneurs, who can commercialize technology products, were generally missing.

As a result, one of the most striking features of underdevelopment in those countries has been and remains their technological backwardness. A large population in developing countries continues to depend on technologies that are incapable of generating levels of income to meet even the most elemental basic needs. These technologies often are also inadequate to transform, without destroying, the natural environment. Since technical changes have been credited in economic theory with being one of the major factors in economic growth, the economic development of developing countries depends, to a large extent, on both the individual and collective ability of these countries to introduce technical changes as an on-going process, as there is a consensus to the direct relationship between science and technology and the socioeconomic development, which in turn is the result of a confluence of many factors: scientific and technical knowledge, management, institutions and proper economic, social and cultural environment, etc.

This paper analyses the functional interrelationship among three social sub-systems that can promote the development and utilization of science and technology with particular reference to developing Africa: (a) the institutional sectors (government and private sectors) which synthesize the goals of society and have the responsibility to establish priorities and to allocate resources to achieve those goals; (b) the scientific and technological infrastructure made up of research institutions, the scientific community, the educational system and institutions created for extension purposes and for the diffusion of science and technology among the populace; financial mechanisms and allocation of resources for research and development and the diffusion of science and technology are part of this process; and, (c) the *productive sector* which is in fact the most important user of the products of science and technology. Section V will appraise the policy implications and brief concluding remarks are given in Section VI.

The Institutional Framework of Science and Technology

In the past three decades, a number of countries have created public and private machineries for the promotion and utilization of science and technology in development. This involved above all the establishment of national institutions for science and technology policy whose names varied from country to country but which nevertheless had the same core functions; namely: (i) to determine priorities for scientific and technological activities and to formulate national policies for attaining suitable objectives within those priorities; (ii) to promote and co-ordinate scientific and technological research in and among relevant private inititutions by providing funding and other supportive services; (iii) to identify the technological needs of local (rural) economic activities and assist in the development or procurement of technologies suited to those needs; and, iv) monitor national policies and evaluate their effects on the growth of science and technology.

However, in the African context, it is the government rather than the private sector that had the responsibility to catalyze the development of science and technology (S&T) and promote and facilitate their application in accordance with the objectives of development. Most of the countries in the

African region have created policy-making bodies for science and technology designed to perform the above functions. The functions of the private sector have not always been supported by adequate funding in view of the cross-sectorial nature of science and technology, the involvement of many ministries dealing with sectorial research and training rather than on application of S&T for development. Recent studies conducted by Atul Wad and Radnor and by UNESCO indicate that by the end of 1986 nearly twenty-eight countries in Africa had some form of multi-sector body for coordinating scientific research and for policy formulation (Atul Wad and Rander, 1983: UNESCO 1986a; UNESCO 1984). An Analysis of the institutional framework for science and technology policy-making shows wide divergences among African countries. In some countries, governmental structures for science and technology policy are still at the early stages of formation while others have come a long way in this respect by establishing governmental science and technology policy-making organs. Countries like Algeria, Cameroon, Congo, Côte d'Ivoire, Ghana, Egypt, Kenya, Morocco, Nigeria, Senegal, Sudan, Tanzania, Tunisia, Zambia, etc. had science and technology policy making bodies; while Benin, Burkina Faso, Gabon, Niger, Togo, needed to strengthen the inter-ministerial mandate of science and technology before they can become truly operational. Countries that lack S&T policy-making bodies but are able to conduct their researches in specialized institutions include Angola, Botswana, Cape Verde, Comoros, Equatorial Guinea, Guinea Bissau, Liberia, Mauritania, Mauritius, Sierra Leone, Swaziland, etc.

Table I shows the trends in the latest available formation of science and technology policy-making bodies in Africa during the period 1973-1986. Considering different sectors like agriculture, medicine, industry, environment, etc. the overall number of policy-making organs increased from 69 in 1973 to 197 in 1986, meaning that, in 13 years, 128 new policy organs were established. Accordingly, the number of ministries responsible for natural science and technology policies increased from 5 in 1973 to 27 in 1986. However, only few were actually ministries of science and technology. The portfolio for S&T has changed hands rapidly in a few countries like Kenya, Tanzania, Senegal, etc. This is principally due to the multi-sectorial nature of science and technology where many ministries have activities in S&T and do not have to be controlled by one particular ministry. Tanzania, for example, has moved from a National Scientific Research Council under the Ministry of Economic Affairs to a National Commission for Science and Technology chaired by the President.

Table 1: The Formation of Science and Technology Policy-Making Bodies (1973-1986)

	1973	1979	1986	New bodies created in the 1973-1986 period
- Ministry of Science or Ministerial Science Policy Council	5	9	27	+ 22*
- Science Planning Body in general	12	18	20	+ 8
- Multisector Body for Coordinating Scientific Research	18	24	28	+ 10
- Natural Science Research	2	16	23	+ 22*
- Agricultural Research	15	30	32	+ 17*
- Medical Research	6	20	21	+ 15*
- Nuclear Research	3	3	4	+ 1*
- Industrial Research	7	22	25	+ 18*
- Environmental Research	1	14	15	+ 14*
Total	69	157	197	+ 128

Source: Compiled from Wad and Adnor 1983, UNESCO 1984, UNESCO 1986

* Indicates bodies with rapid increase.

Though Table 1 shows a positive trend in the growth of science and technology policy-making bodies, it does not in anyway bring out the effectiveness of these bodies which have been biassed towards research, and have given little attention to the application of S&T.

Thus, in the African context, it is the public sector that plays the lead role in endogenous capacity building for materials technology, for the private sector is usually weak, and has only recently started playing any significant role. Institution building requires heavy investments which the private sector cannot afford in the beginning. It is up to the public sector to finance such institutions like University departments or centres for training and research in materials science and technology; specialized laboratories for testing of materials like building materials, cement, rice-husk, jute, polymers, glasses, ceramics and metals; national standards bureaux for establishing standards, quality-control, certification for manufactured products using locally available or imported materials, centres for technology transfer dealing also with technology assessment, patents and industrial property. The public sector also encourages the private sector to join hands in many of these institutions by giving them adequate incentives through various legislation. Most of the incentives are centred around 'risk and cost reduction' for private sectors undertaking research and development and setting up pilot units for testing products and processes, and finally commercializing them.

The risk and cost reduction incentives are of three types; financial, fiscal and institutional incentives (Kim, 1984). In order to encourage a private industry to undertake research and development in new materials technology, besides helping the firm through *financial incentives* in the form of low-interest lending programmes by national banks, and through commissioning of R&D activities to them, or through *fiscal incentives* in the form of tax deductions, accelerated depreciations and reductions in duties for imported items meant for R&D, the government may attempt to establish a National Research and Development Corporation (NRDC) that enables the public sector and the private sector to take research results from the laboratories to the consumer in the form of marketable products. The National Research and Development Corporation often groups together the researchers, the policy-makers, the private entrepreneurs, the bankers, the market specialists and the consumer representatives around one table and enables them to decide on priorities for development research, and on ways and means to commercialize research results. The main functions of such an institution (Jugessur, 1990) are: (i) decide on projects that need to be financed; (ii) collect and sift research results from different centres, institutes, faculties, research laboratories that have potential for commercialization; (iii) mount pilot projects to verify the results; (iv) make prototypes and test their efficiency; (v) demonstrate these technologies to users and guage their acceptability; (vi) contact local entrepreneurs and offer them the necessary incentives to mass produce the products; and (vii) promote their commercialization locally and abroad. Such an institution has been instrumental in the overall technological development instrumental in endogenous capacity building for materials technology in Africa.

Another institution that had contributed to the promotion of science and technology in Africa is a Centre for Technological Transfer that is found either in a university or as an institution directly under the Ministry in charge of Science and Technology. This centre has been responsible for all aspects of technology transfer, including technology assessment, technology forecasting, dissemination of relevant information on available technologies, a data base for patents and industrial property, and for facilitating the registration of new patents. In liaison with research and development centres, it has been also a major arm of the National Research and Development Corporation mentioned earlier. The Centre for Technology Transfer deals with many new materials that are coming in the market as a result of development of the frontiers of science and technology. Some of these materials may have a negative impact on the markets of locally produced materials. The Centre keeps tracks or monitors these new developments on the international scene, assesses the nature of these technologies, and forecasts their impact on local developments. Sometimes, it is possible to use these new technologies to enhance one's own production processes, or final products and the acquisition of these technologies becomes essential for staying in a competitive market. Patents and industrial property offer a mine of valuable information concerning technologies, either in the public domain, or that are time-bound. The acquisition of the relevant information becomes easy when there is a local institution that can gather the necessary data, store them and disseminate them locally. In many African countries, whenever an innovator has come up with new designs, products or processes, he has had difficulty in knowing who to approach for patenting his innovation. The existence of a patent office within the Technology Transfer Centre can be very effective in promoting local talents in the area of technology development, including new materials technologies.

The Scientific Infrastructure

As for the science and technology infrastructure, trends have been identified as affecting several elements, namely (a) the educational system responsible for the production of the human resources needed in terms of quantity and quality; (b) the quality of research and researchers, and the adequacy of research centres located in the universities, government departments and the productive sectors; (c) the co-ordination and planning of science and technology and the administrative and financial tools needed for the implementation and management of science and technology activities; and (d) the extension system that would carry the results of science and technology to those who need it most — the rural people and the marginalized sectors of society like women.

The Educational System in Africa

One of the key bottlenecks of S&T development in Africa is the dearth of qualified S&T personnel, the provision of which depends greatly on the performance of the educational system. The situation in Africa in relation to all these elements during the past say five years provides food for thought. To begin with, the educational system in most African countries is hardly oriented to the production of a science and technology linked to the environment or developmental purposes. Apart from a few countries like Botswana, Cameroon, the Great Libyan Arab Jamahiriya, Malawi, Ghana, Zambia and Swaziland, there is a dearth of adequately qualified manpower in the whole African region for science and technology development and application. Even in these countries, the highly trained manpower in S&T have not had the opportunity to occupy themselves gainfully in the absence of infrastructure for commercialization of Research and Development (R&D), and a strong private sector involved in R&D. This has led to brain-drain and a loss to the countries.

Skilled technicians are lacking, and most African countries suffer from lack of input from qualified people, because their educational system has concentrated either on basic education (French speaking countries) or high level specialized training (English speaking countries), forgetting the middle-level technicians and virtually neglecting the science and technological training so essential for any industrial development. It is recognized that for every engineer trained, there should be at least ten technicians trained. Only then can the engineer do his job properly; otherwise, he will end up as an administrator or manager, and actual engineering and technological development suffers. The informal sector is the major contributor in production of goods and services in most African countries but this sector unfortunately employs mostly unskilled or semi-skilled manpower, craftsmen and technicians. Engineers keep away from them because they feel it is not up to their standard of education. The French speaking African states have stressed more on scientific research and training than on technological research and development. Hence, they have produced scientists of high calibre, who have unfortunately not found the proper outlet for their knowledge, and have often left their countries for better climes. In English speaking African states, however, there are small and medium scale industries which have enabled the trained scientists and technologists to find their feet, though even here there is room for improvement (Eisemon et al, 1982).

At the Secondary School Level

A question is raised here: should high schools concentrate their training primarily on basic general science education (Franco-european type of educational system) or should they start already specialized training or technology education (Anglo-American type of educational system)? In our view, high school pupils should grasp fundamental principles of science properly (the first category) while at the same time they should be given an opportunity to handle equipment and experience things through practical experimentation (the second category). In other words, there should be a close link between science and technology in the training of high school students. Technology is not necessarily applied science. Science is codified and systematized knowledge which has the power of explaining certain phenomena, and as such it is different from technology and technology is not always a product of science. Advances in science are mainly dependent on the state of the art of technology itself and especially old technology.[2] Thus, although science and technology are structurally independent, there should be a much

2 For example, the African traditional knowledge and know-how have not been elevated to the rank of science. It has been transmitted through the ages, it is practiced but it is not well and thoroughly organized in a scientific manner.

stronger relationship and interaction between the two in the courses at the high school level. Indeed, material science and technology deal with the science of internal atomic and crystalline structures of materials, and the technology to manipulate these structures in order to produce new materials of different required characteristics. In most cases, the materials developed have improved mechanical, or optical, or chemical or electronic characteristics and performance. Where mechanical properties are the main target, the materials developed are smaller, lighter, stronger, longer-lasting and often recyclable. The manufacturing processes often aim at using less energy and at being environmentally more attractive, and ending up with products that have more knowledge and information content and a greater added value.

In order to bring these concepts to aspiring materials scientists and technologists, it is essential for the high school students to have a proper curriculum in physics, mathematics, chemistry and biology bearing in mind time and space (i.e. universal history and geography). At the same time the science laboratories should be equipped for practical class demonstration. It is here that the basis for higher science and technology studies is established. In developed countries, the school syllabus and laboratories are under constant review, and the teachers are regularly retrained. This is not often the case in Africa. Most of the African school laboratories are stocked with equipment acquired fifteen or twenty years ago and some date from the colonial period. Most of the school laboratory equipment is imported. Due to rising cost, the laboratories are unable to replace old, out dated equipments which are still utilized for class demonstration. The need to manufacture science equipment for schools to meet the demands of the region has been stressed in several fora, but up to now there is not a single manufacturing institution able to satisfy even the national needs. There has been no recurrent budget for replenishing or improving the laboratories, with the result that the students leave the high school with limited scientific knowledge that do not really enable them to understand even basic concepts of science and technology. No amount of money poured in the university laboratories will enable high level manpower to be trained, if their basic science and technology training in high-school is weak. It is towards the improvement of this basic training that national and international efforts must be concentrated so that endogenous capacity building in science and technology in general and in materials technology in particular, becomes effective. As Dr Frank Kwan Codjoe (1990) indicated:

> *Science subjects should become compulsory, especially mathematics, physics and chemistry, in all secondary schools up to six form levels. More science teachers should be trained. The standing, esteem and respect of teachers at all levels should be raised and maintained; They*

should be given better pay and benefits to allow them to do a better job.[3]

In the light of the above, there needs to be an overhauling of the entire system of science education in the developing regions. Mass manufacture of school science equipment, improvement of laboratories, greater incentives to science teachers, upgrading and updating of the science curricula, closer link of this curriculum with the local environment, etc. are all urgent imperatives in the process of endogenous capacity building. All students of high schools should be given the opportunity to grasp both the basic universal science education and the practical class laboratory demonstration in order to enable them to understand the basic concepts of science and technology, before they further specialize at the university level.

At the University Level

With new developments in materials technology, university courses in materials science and technology are integrating areas of applied chemistry, geology, mining, metallurgy, civil and electrical engineering. Specialized courses in surface physics, fracture mechanics, polymers, superconductors, etc. are being organized in developed countries. There is need for an inter-disciplinary approach to the teaching of these courses. On the engineering side, various raw materials are studied in order to transform them to fulfill specific engineering needs. There are five classes of materials presently under study and development: (i) Civil engineering materials concerned with building and construction, like cement, concrete, bricks, clar, plaster, etc; (ii) Structural materials including metals, polymers, composites and ceramics; (iii) Renewable materials like wood, agricultural by-products, horns, hides, etc.,; (iv) Functional materials including semiconductors, optical fibres, solar cells, magnetic and superconducting materials; and, (v) Biomedical materials used in prostheses and repair of human body parts, orthopedics, etc. The courses related to materials science and engineering are linked as shown in Figure 1.

In the African region, most of the research and development work is concentrated around the first three classes, but in the Western or developed countries, new materials are being developed in the last two classes. In fact the greatest work has been in the area of functional materials which are now on the market, except for superconductors. With these considerations in the background, university curricula have to be reoriented so that the people

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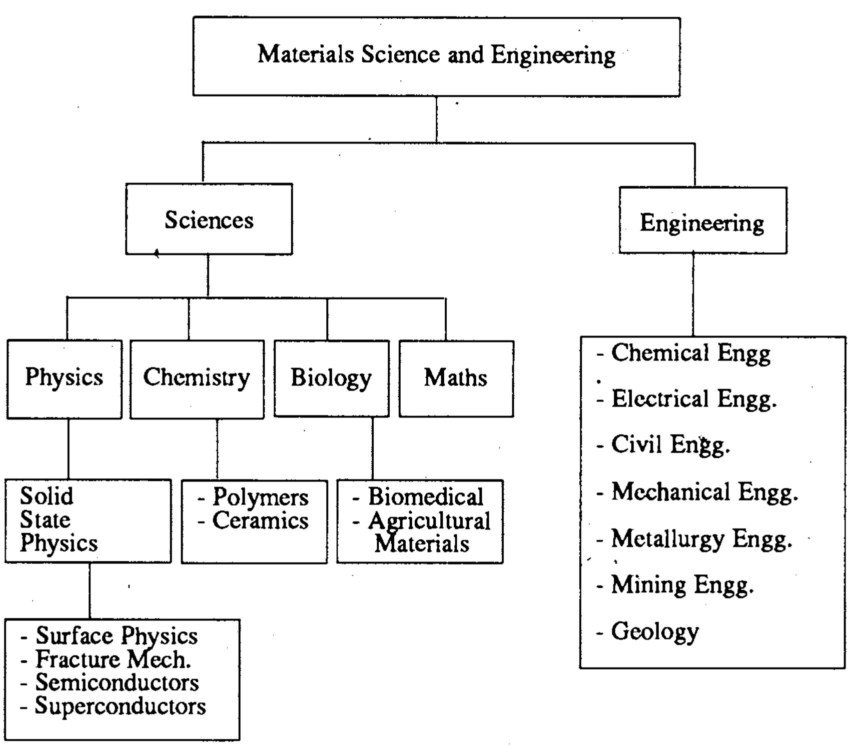
3 For instance, the Buisseret's high school programme introduced in the former Congo (now Zaire) in the late 1950s has successfully initiated such an all-embracing teaching method to provide the students with basic universal knowledge, but unfortunately the programme was short-lived.

trained at the tertiary level should be able to contribute to a much greater extent to finding solutions to the issues of raw materials in their region. The present solution, as highlighted above is such that a few research institutions are working on civil engineering, structural and renewable materials. But at the university level the curricula do not reflect these needs, and classical courses are still being taught. Most of the university graduates are in social and human sciences (80 per cent) at the expense of natural sciences, engineering and technology (20 per cent). There is the need to organize degrees, undergraduate and graduate, in materials science and engineering. The problem that arises in Africa is how and where to obtain the lecturers and the laboratory facilities for such courses. While local lecturers can be sent on training to developed university centres abroad, they can be replaced by qualified expatriate lecturers, either on a loan basis or on co-operative exchange agreements. The qualified expatriates can bring with them a wealth of experiences and help in establishing the curricula and laboratories necessary for such courses. The successful experience of Asian countries is worth emulating.

Figure 1



Courses related to materials science and Engineering

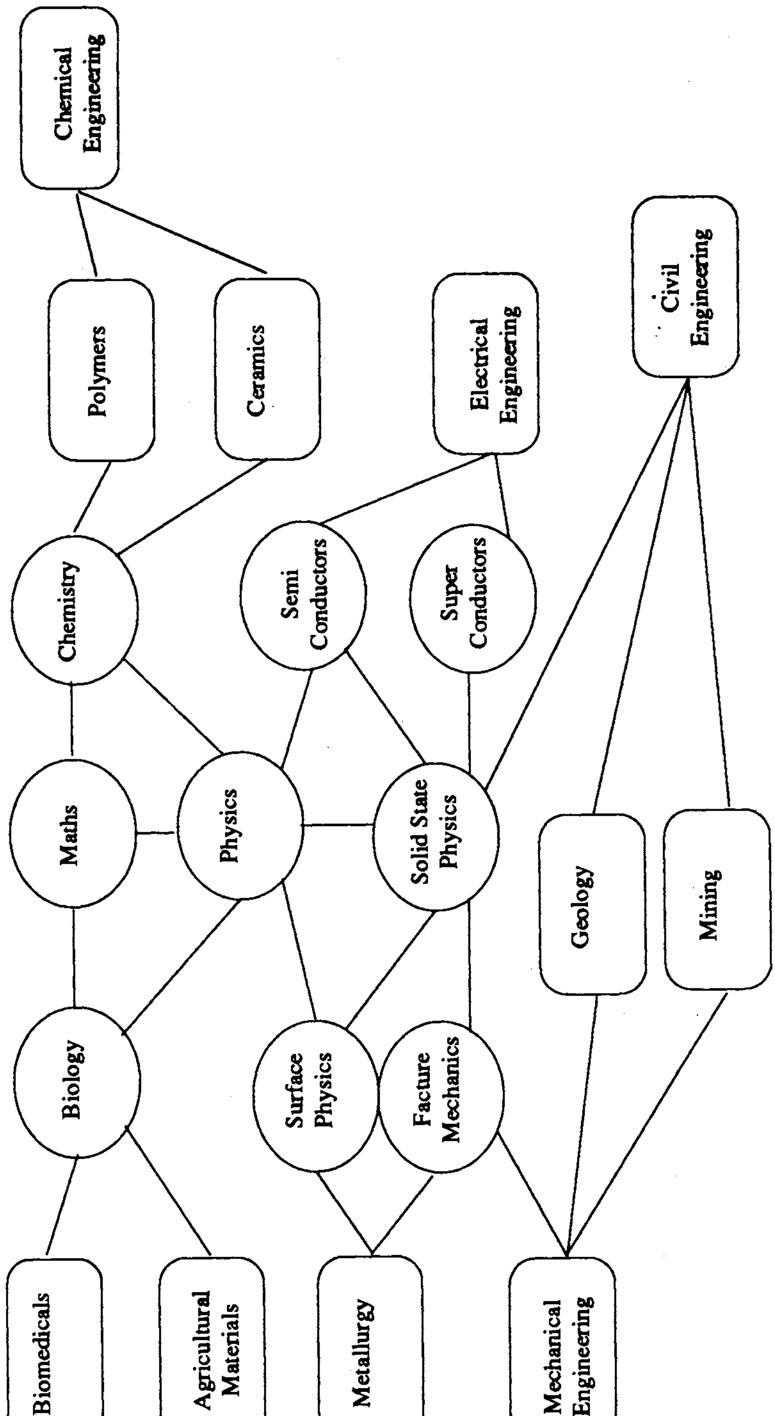
One way is to take the project approach in enhancing the endogenous capacity in materials technology, whereby the African university can settle on a well-chosen collaborative project with another university in the developed countries where the laboratory facilities and technical personnel are available. Both universities agree on the objectives of the project that should be beneficial to either party, and on the sharing of research and development results. The raw materials under study are provided by the African counterpart. A complementarity of technical capabilities and facilities is necessary, and in the process of exchange of staff and collaborative research, the developing country can assimilate the science and technology package, acquire the necessary skills, organize its own laboratories that can eventually test the materials produced, and commercialize the products. An interdisciplinary approach is necessary in this venture for, besides dealing with specialized scientific or engineering issues, the process of production and commercialization of the manufactured goods. This approach will require a close collaboration of management and marketing experts, bankers and entrepreneurs, and people from varied disciplines. In fact, the multi-disciplinary approach should be inherent right from the choice of the collaborative project.

The Quality of Research and Researchers

The industrial relevance of university courses and research programmes is a primary factor that determines the socioeconomic development of a country. The stress on academic distinction and on high level intellectual pursuits for the sake of universal culture and knowledge has tended to keep the universities in developing countries as ivory towers, often far from the realities of the environment in which they exist.[4] Most of the university funding comes from the governments in power who often view the universities more as institutions where they can place their proteges than as institutions that can contribute to the solutions of socioeconomic problems. The contribution of the private sector to the running of universities has been marginal, for close university-industry collaboration has been minimal. This may explain why many graduates from universities cannot find employment in the industries, for they have had nothing to do with the industries. They depend solely on the governments for employment. In most countries, the saturation of public sector's jobs has brought unemployment among university graduates, even at

4 The situation exists even in some developed countries in which university teachers and students concentrate on intellectual and academic exercises without being in tune with the realities of their natural environment and research results remain highly theoretical and published in academic journals or reviews which, in general, do not suggest practical solutions to the socioeconomic problems confronting the policy-makers (government and private enterprises) in their daily running of the country.

Figure II: Materials Science and Engineering Linkages



the PhD. level, despite the expansion of the public sector witnessed in recent decades in many industrialized countries. Private productive sectors prefer to employ people whom they know, and this is possible through collaborative programmes, and research projects with universities. The practical and industrial training of undergraduates in science and engineering courses can be organized through close universities contact with industry. The universities gain in the process, and endogenous capacity building is facilitated. Such collaboration can even create new industries or branches of industries and therewith new job opportunities as a result of new inventions by the industry-university joint ventures.

Thus, to enhance the quality of technological research and researchers, there must be a close collaboration between the industries and the universities. Industries that require advanced technologies innovation so as to stay in a competitive market, have advantage in contracting research to universities where the facilities exist. It will take a long time for African industries to acquire their own research and development centres. Hence industry-university collaboration is the means for achieving enhanced capacity in the field of industrial and technological development. This collaboration can increase the income of the universities which will then be less dependent on government funding. Indeed, in many Western developed countries, industries have even established a cell or a centre in the university campuses, in what is known as a science and technology park. Industries rent factory units at favourable rates and have ready access to the laboratory facilities and expertise within the campus. This has enabled an enhancement of the ties between the university, industry and local entrepreneurs, more relevant research and development programmes, consultancies for university staff, testing and quality control services to the universities, technical training for students and their eventual placement in the mother industries. There is also an interchange of staff between the industry and the university on short-term assignment, and an increased income for the universities.

Because of the fact that industries are the main consumers of raw and finished materials, such a collaboration between industry and university can go a long way in promoting relevant training of scientists and technologists and in endogenous capacity building in materials technology. The transfer of technologies from abroad, and within the countries, is facilitated by such collaboration, and new enterprise development within the country becomes possible. Materials available locally can be enhanced by adding value to them, and enabling the manufacturing or building sector to use them to advantage. Their export market will also be improved and thereby the country will benefit from increased income. Government policies encouraging the participation of the private sector and the industries in endogenous capacity building will necessitate suitable legislations providing incentives in various forms. High level manpower training in materials technology through university-industry collaboration can indeed benefit from such legislations.

Table 2: Economically Active Scientists, Engineers and Technicians as per Million Inhabitants in Different Regions of the World

Region	R&D Scientists & Engineers			Technicians	
	1980	1985	1990	1980	1985
- Africa*	84	72	74	831	1376
- Latin America	242	312	364	9754	11759
- Asia*	304	336	396	8985	11730
- Arab States	330	336	363	7046	9143
- Oceania	1774	1414	1610	36941	48213
- Europe	1859	1927	2206	35714	48600
- North America	2734	3024	3359	96023	126200
World Total	894	920	1000	18200	23442

Source: UNESCO (1991).

* Excluding the Arab States.

So far, however, the number of scientists and engineers trained in African universities and polytechnics is far less than what is needed for basic development. In terms of number per million inhabitants, as indicated in Table 2, the African region had about one fifth of the corresponding figures in Asia for 1990 and only 3 per cent of the level in Europe. The number of scientists and engineers engaged in R&D activities is very small in all the African countries indeed, compared to size of the population and the needs of the region. Much of the problem is due to the lack of adequate educational infrastructures and research facilities for highest education. According to UNESCO's data, the average figure for scientists and engineers engaged in R&D per million of population in the African region was 84 in 1980 as against 304 in Asia, 242 in Latin America, 330 in the Arab States, 1774 in Oceania, 1859 in Europe (excluding former USSR) and 2734 in North America. However, there was an increase from 20 in 1971 to 84 scientists and engineers per million inhabitants in 1980, which declined to 74 in 1990; whereas the other developing regions had a steady increase in the number of R&D scientists and engineers. The number of scientists and technical manpower in the African region like for all the other regions rose from 831 in 1980 to 1376 in 1985. Table 3 gives a global distribution of R&D scientists and engineers in the world.

Table 3: Global Distribution of R&D Scientists and Engineers (Estimated Percentages by Major Areas)

Region	1970	1975	1980	1985	1990
- Africa	0.3	0.4	0.4	0.7	0.7
- Latin America	1.5	1.8	2.4	2.8	3.1
- Arab States	0.6	0.7	0.9	1.4	1.5
- Asia	17.4	18.6	18.5	20.9	22.8
- Europe	22.0	22.6	22.3	21.3	20.9
- USSR	36.6	37.8	36.6	33.8	32.4
- North America	21.8	17.3	18.0	18.2	17.8
- Oceania	0.0	0.8	0.9	0.9	0.8
World	100.0	100.0	100.0	100.0	100.0

Source: UNESCO (1991); UNESCO (1986b:V. II.)

Policy Coordination and Financial Requirement

Countries which depend heavily on either export of raw materials or import of processed materials, along with their science and technology policy and plan, also have formulated national materials policy based on assessment of world market situation and forecasting of local needs in the short, medium- and long-terms. Such materials policy took account of the subregional and regional needs in order to avoid the competition within the same region which would affect the market value of the materials produced.

As to the funding of science and technology (S&T), the R&D expenditure as a percentage of Gross National Product (GNP) and the classification of countries according to the number of S&T personnel per million of population, are shown in Table 2A in annex, in comparison with the developed countries. It can be seen from the table that most African countries (21 of them) have spent less than 0.2 per cent of their GNP in R&D activities: 15 countries spend between 0.2 and 0.4 per cent of the GNP, while 7 countries spend between 0.5-0.99 per cent as of 1980. Recently a few countries, including Egypt, have met the target of 1 per cent of their GNP market for S&T activities, as recommended in the continental development programme: the Lagos Plan of Action (LPA). These can be compared with what the developed countries spend on R&D, where, in many cases, they go far above 2 per cent of GNP. This comparison is reflected also in Table 4. It can be seen that Africa has been losing its share in the world distribution from 0.3 per cent in 1975-1980 to 0.2 per cent in 1985-1990, whereas the Asian countries have gained. Thus, the African region as a whole has not been able to meet the target of 1 per cent of GNP in the eighties because of the adverse and critical economic conditions it was facing. Inadequate funding of S&T activities leads to a weak S&T to exploit the natural resources, or to develop the continent through agricultural and industrial developments.

Table 4: Global Distribution of R&D Expenditure (Estimated Percentage by Major Areas)

Region	1970	1975	1980	1985	1990
- Africa (1)	0.2	0.3	0.3	0.2	0.2
- Asia	7.3	10.8	14.8	16.2	19.5
- North America	44.5	33.7	32.1	42.6	42.8
- Arab States	0.2	0.3	0.5	1.3	0.7
- Latin America	0.8	1.5	1.8	1.1	0.6
- Europe	25.3	32.0	34.0	24.1	23.2
- USSR	20.9	20.4	15.6	13.7	12.3
- Oceania	0.8	1.0	0.9	0.8	0.7
World	100.0	100.0	100.0	100.0	100.0

Source: UNESCO (1991); UNESCO (1986b).
(1) excluding Arab States

Adequate working and living environment for scientists and technologists demands higher government input in terms of funding. Apart from a few French speaking states of West Africa which receive external funding for R&D, in most African countries nearly 100 per cent of the funding come from national government, the major employer of S&T personnel. Whereas the contribution of the private industrial sector to R&D in developed countries is over 50 per cent, in developing Africa this is marginal.

Extension System of Testing and Quality Control

The testing and quality control of materials produced locally or imported are essential for product reliability and quality that dictate the market. Laboratories for these often require very costly equipment which single manufacturers in Africa cannot afford. Government laboratories have often undertaken such testing for building materials. With the setting up of industries, National Standards Bureaux with their own testing facilities have evolved. Universities also have laboratories with equipment for such testing, and have, on ad-hoc basis, helped private industries. Existing infrastructure in teaching and research institutions can be used optimally by allowing them to undertake contract testing from the private sector involved in materials use and professionals involved in testing, provided the university and government authorities encourage such activity and willingly reward the workers including the rural farmers and women through appropriate incentives.

Utilization of Science and Technology in the Productive Sectors

Science and technology have been evaluated as a global phenomenon, whose integration in the production process differs between developed and developing countries. In the former, such an integration takes place through linkages with the production sectors, which orient and provide resources for research and development and, finally 'consume' the resulting innovation. The research and development integration with the productive activity frequently reduce the time lag between the research phase and the commercial production of innovations, hence accelerating the diffusion phase and the economic growth. Nowadays several developing countries are also moving away from purely theorizing and intellectual exercises, towards developing science and technology that effectively contribute to enhance the productive sectors of their economy, including agriculture, manufacturing industry, mining, energy and water, and construction. In other words, they seek to find a close link between science and technology and the production of basic needs (goods and services) of their population. However, in developing countries the utilization of science and technology in the productive sectors requires seven different stages (UNECA, 1991):

i) **Appreciation of a technological age** which requires the popularization of science and technology concepts, their advantages and disadvantages in a growing economy, their place in the fight against poverty, illiteracy, disease, and in the improvement of the quality of life of people living in harmony with nature. This is achieved through popular radio and TV programmes, village and community participation in scientifically biassed art and drama, science and technology clubs for youth, moving exhibitions of new products and processes, incentives and prizes to local innovators, etc.

ii) **Improvement of formal curricula in schools and colleges** which stresses science subjects, and on multidisciplinary materials courses at university undergraduate and post-graduate levels, that is, the formal training given by the government (and rarely by the private sector).

iii) **Application of basic knowledge in science and technology**: With the formal training received at schools and colleges, informal sector workers as well as those in organized small and medium scale industries can apply their knowledge to improve existing technologies and thereby improve productivity and quality. The blending of new and traditional technologies can be achieved through this process.

iv) **Implementation of imported technology**: This is a still higher stage involving research and development. Here research has to deal with technology assessment and technology negotiation in order to ensure a proper technology transfer at reasonable costs. At this stage technologies are imported in an unpackaged form and not as black boxes, and the process of reverse engineering whereby an equipment is pulled apart into its different components, and reassembled, often with newly improvised parts, is mastered.

v) **Assimilation for product diversification**: This stage involves research for adaptation of imported technologies, using locally available materials and resources. This eliminates the dependence on imported materials, lessens the costs of production, and often makes the technology available to a greater number of manufacturers.

vi) **Improvement for enhancing competitiveness**: Here fundamental research and development follow. New products and processes are evolved through high level R&D, and they become more competitive in the world market. It is here that the number of patents registered increases very fast.

vii) **Large-scale manufacture and marketing**: The products developed through high level R&D are then manufactured on a large-scale by well-established firms, often having multi-national antennas and aggressive marketing.

The seven evolutionary stages mentioned above are being implemented in varying degrees in African countries. The situation concerning materials technology is far from satisfactory. Most African countries have not even tackled the broad issues of science and technology globally. Only a few selected universities have specialized laboratories doing basic research on the use of local materials, especially in the area of research and development. Most of the research output have however stayed in research publications, and little commercial exploitation has been realized. In addition, scientific production is still concentrated in a selected number of fields, of which life science account for a heavy concentration and only ten countries (Cote d'Ivoire, Ethiopia, Kenya, Nigeria, Senegal, Sudan, Tanzania, Zambia, Zaire and Zimbabwe) supply almost 90 per cent of the region's total scientific publications. Technology development is slow if not inexistent in some countries, despite the realization that the driving force behind the advent of new and frontier technologies in the developed industrialized countries is the development of substitute materials for raw materials that were once imported from the developing countries and thereby shifting the base of their economy. Such development has tremendously reduced the importance of African commodities and thereby negatively affected their market. Unless Africa masters these technologies and uses them to advantage by enhancing their market value through processing, income from export of pure raw materials will gradually decline.

The most striking trend characteristic in Africa has been the emphasis on the process of linear transfer of technology. In developing Africa, unlike other developing regions, the links between the scientific and technological sectors are, at the present, very weak, while those between research and development activities and the productive system are almost non-existent. Most African countries imitate the organization, structure, purposes and methods of the research and development activities of the developed world, while their scientists and technicians consider themselves as members of the world community of scientists, with loyalties and responsibilities to that community rather than to the home base. Inevitably, the developing African countries are hindered from establishing a scientific and technological base linked to their productive activity and conscious of the constraints and potentialities of its natural environment.

So far, developing African countries have thus become consumers of an imported technology which they have done nothing to generate. The assumption has been that the absorption of foreign technology could raise the socioeconomic system towards higher levels of development (Spencer, 1967). This indiscriminate and uncritical acquisition of alien technology has led to increasing dependency, for the mere assimilation of technology implies the acceptance of a linear concept of development and suggests that the stages that have characterized the development of industrialized countries would have to be replicated in African countries. But modern industrialized societies have developed technologies in accordance with their own peculiar characteristic, and the interrelationship between their resources, capital and environment. These technologies are not well adapted to the circumstances of African countries, but rather to conditions of labour scarcities, capital abundance, and large markets which permit the exploitation of economies of scale leading to a reduction of cost per unit of production.

The Agriculture Sector

For instance, agricultural technologies and practices developed in temperate areas of the developed world were directly duplicated or indiscriminately copied in several African countries. Such uncritical transfer of technology in agriculture has failed or, at least, has not reproduced the good results in productivity. In fact, as recommended in the continental development programme alluded to earlier (the LPA), several countries devoted between 60-80 per cent of their resources allocated to national scientific and technological research to agricultural research. But this agricultural research generally focussed more on perennial or cash crops than on food crops. As a source of new technology, research has aimed at increasing crop productivity and disease resistance of major export crops. Research has also focussed on improving agronomic practices, including the use of modern inputs such as fertilizers and development of improved tools and use of animal traction. Although the genetic base of most perennial crops such as coffee, oil-palm, cocoa, coconut palm, etc, has deteriorated in recent years, historical evidence shows that research efforts especially during the colonial period concentrated on these crops leading to the breakthroughs in the development of hybrid oil-palm in Zaire, Nigeria and Cote d'Ivoire; tea in Kenya, cocoa in Nigeria, Ghana and Côte d'Ivoire and Arabusta coffee (hybrid of Robusta and arabica) in Zaire. These crops traditionally regarded mainly as men's crops were developed in order to satisfy the demands of the world market rather than local needs.

In the food crops production, the results were even more limited, judging from the problems of food shortages the African countries are facing. For example, as early as the 1940s the British peanut scheme in Tanzania was one of the most spectacular failures: 1.2 million hectares of land were allocated to a giant peanut scheme at the cost of £35 million (British pounds), but the area did not get the needed amount of water. After ten years, the area was eroded, turning, in the dry season, into a cement-hard desert. Apart from the Green Revolution type breakthrough in hybrid maize in Zimbabwe and Kenya during the colonial period, there have been no comparable breakthroughs in research for the food crop subsector dominated by women. Even at present most research activities are related more to cash/export crop rather than to staple food crops. It has been reported that only 24 per cent of agricultural researchers working in Sub-Saharan Africa were specialized in sorghum and millet whereas these two crops account for more than 45 per cent of the region's cereal production and occupy about 60 per cent of the area devoted to cereals.

After a 12 year research programme, a promising variety of sorghum was released in the Sudan only in 1984. Maize has been relatively neglected in West Africa and it is only recently the research on maize streak virus by the International Institute for Tropical Agriculture (IITA) was undertaken, whereas in Southern Africa (notably Zimbabwe, Zambia and Malawi), the genetic research base for maize has been undertaken. Research on grain legumes — phaseolus beans, cowpeas and soy beans — has been modest until recently and several regional research projects on these crops are getting underway in East and Southern Africa. Finally, such other crops as roots and tubers (sweet potatoes, yams, cocoyams) which are important staple food crops in coastal West Africa and Central Africa are only now receiving modest research focus particularly from the IITA. Not much information is available on research, if any, on plantain, also an important crop in West, Central and parts of East Africa (Kenya, Uganda and Tanzania).

It has been observed that on average, between 60 and 80 per cent of the total resources allocated to national scientific and technological research in African countries is devoted to agricultural research. Although encouraging results have been obtained in research on cash crops as well as on staples. Increase in yields is at times very significant to the extent that yields obtained in research stations are, at times 3 to 5-fold of those obtained on traditional farms. However successful result have yet to be obtained in developing new varieties of rice and wheat and in the production of compost manure. Nevertheless, due to the low level of technological know-how of the African farmers and the absence of appropriate extension services, the real impact of all these research results on agricultural production in African countries is still limited.

The Manufacturing Industry

On the other hand, the industrialization process based on import-substitution is no better. In a great measure it has been associated with strong economic protectionism from foreign competition which contributes to the creation of local entrepreneurship that is not concerned with improving productive capacity and efficiency through local research and development. The situation is aggravated where governmental policies grant almost unconditional terms for imported technology in the form of patents, equipments, semi-finished products, technical personnel and consultants. All these factors undermine confidence in the internal capacity to supply technology, hence weakening even more the already extremely fragile links between the science and technology systems and the productive system. This process is not helped by the attitude of foreign industries, particularly transnational corporations, who have their own sources of know-how and technology to draw upon. Developing indigenous capacities is simply not one of their priorities.

Thus, the impact of national science and technology on the industrial production in the African countries has been and is still very limited. There is a complete contradiction between the desire for economic independence and the industrial policy pursued, the latter being essentially based on imported advanced technology which neither takes account of the local situation nor of the skills of the domestic labour force. Factories in the region are very often no more than branches of a big industry based in the European parent countries, and most of them are essentially concerned with packing and marketing products from parent companies abroad. Consequently, the African states become technologically highly dependent on their industrial development process.

The Mining and Energy Sectors

The economy of each African country is unfortunately precariously tied to the export, in most cases, of a single mining or energy commodity. Thus Zambia and Zaire depend heavily on copper; Algeria, Gabon and Nigeria on crude oil; Guinea on Bauxite and Liberia on iron ore. New materials developed in the industrialized countries replace these minerals and thereby reduce their market value. Moreover the technologies for their exploitation and processing are archaic, and the advent of new technologies for these has yet to be taken advantage of. There has been a symbolic relationship between the government, the public and private productive sectors, and those involved in research and development will stress on the exploitation of research results aiming at producing energy-saving and cost-saving high performance materials which will substitute conventional materials and building materials. Ceramics, optical fibres, synthetic and composite materials and high performance metallic alloys are coming on the market, and African R&D have to reorient themselves towards the blending of these with conventional materials and exploiting them commercially.

Rare earth minerals have enormous potentials now and for the future for use as raw materials for photovoltaic, photonic, sensors, new fine ceramics, special plastics, and superconductive, magnetic and functional electronic materials. Fortunately Africa has an abundance of these rare earth minerals in the form of beryllium, lanthannum, chromite, strontium, yttrium, zeolite and others. What is required is a systematic inventory of these and their extraction and exploitation, as they are likely to pay high dividends in the future. The same is the case for non-metallic minerals which are in high demand as they are being used in mineral-filled plastics and low-cost polymers. The new and emerging technologies in the area of new materials and products relevant to African minerals and building materials are: ceramics technology, optical fibre technology, new polymeric materials technology, typical composite and materials technology, new metal processing and production technologies, functional electronic materials technologies, and small diameter wood technology. A few developing countries outside Africa are already mastering many of these technologies for their own survival.

In order to avoid negative impacts of these new and emerging materials technologies on the market of African minerals and raw materials, African States should prepare themselves by training requisite manpower, setting up new institutional infrastructure for materials science and technology and improving their production processes using these technologies. There has been a decline in the consumption of iron ore in steel making as a result of improved technologies in iron and steel making. The average steel content in motor vehicles is gradually decreasing and new composite materials are replacing the steel. Similarly there is growing decline in the demand for copper, tin, lead and zinc, while demand for nickel, cobalt and titanium is likely to increase. The replacement of metallic mineral ores with advanced new materials will definitely affect the mineral market adversely in Africa.

The Construction Sector

In the area of building and construction materials, Africa is rich in building and construction stone, limestone, gypsum, granite, sand, asbestos, fibres and wood. Modern conventional building materials include cement, bricks, concrete, plaster, steel, glass and wood-based composites. Most of these are imported, with little produced locally in some countries. There are also the so-called traditional materials like earth, stone, thatch and bamboo, which are utilized by most of the population. Finally a third category of building materials has evolved through research and development, like pozzolona, earth-stabilized blocks, ferro-cement, bamboo reinforced concrete, etc, which can offer cheap alternatives to imported materials, and can be quite efficient. In a few cases pilot plants have been set up with government help, as in the case of Ethiopia where possolana blocks have been made, but commercial large scale exploitation is still far away because the private sector has not taken any active part in the whole process. In Ghana, the Building and Road Research Institute for the Council for Scientific and Industrial Research, which is one of the oldest applied research institute in the continent, has succeeded in testing sand-lime bricks, laterite soil-cement blocks, and is promoting labour intensive hand-moulded brick production technology (Gadigasu, 1988).

In Nigeria, the level of research and development is higher, and work at the Federal Institute of Industrial Research Organization (FIIRO), the Project Development Agency (PRODA), the Nigerian Building and Road Research Institute (NBRRI) and the National Research Institute for Chemical Technology (NRICT), are tackling not only building materials, but also industrial engineering materials, semiconductors, polymers and plastics (Koleoso, 1988). However, commercial exploitation of results is still far away. But in the area of food processing, textiles, ceramics and vegetable oils and fats, FIIRO has been successful in developing improved technologies, a few of which are now in the market.

The Tanzania Industrial Research and Development Organization (TIRDO), the Kenya Industrial Research and Development Institute (KIRDI), the Housing Research and Development Unit of the University of Nairobi, the Materials Research and Testing Department of the Faculty of Technology at Addis-Ababa University in Ethiopia, the Central Materials Research Laboratory of the Ministry of Works and Housing in Kampala (Uganda), are a few of the institutions in East Africa that are carrying on research and development in materials related to building and construction, but their main contribution has been in the testing of materials required for such activities in the public and private sectors. It is heartening to note that only those countries that have established policy institutions for science and technology also have research and development institutions to work on materials technology.

From the above trend of analyses, it can be said that while the *government* has the responsibility to catalyse the development of science and technology and promote and facilitate their application in accordance with the objective of development, the scientific and technological *infrastructure* should provide society with the capacity to create, adopt and transmit knowledge. The *productive* sector, both public and private, has also an important role to play in the scientific and technological development directly through their participation in, or support of, research and development activities undertaken by the governmental or private institutions, universities and research centres. Interaction among those three sub-systems is a pre-requisite if science and technology are to become a dynamic factor in development. But what is of crucial importance is the way the scientific and technological results are put in use in the productive sectors to produce new industrial and/or agricultural materials for the satisfaction of the basic needs of the population. The time when universities theorized for the sake of theory and mere intellectual pleasure is long past gone. If the developed countries can afford to do it, developing countries should devote their scarce resources to keeping close link between university and productive sectors of the economy and to producing university graduates who can at the same time grasp the practical problems of their natural surrendings.

Policy Concerns

Developing indigenous technology cannot be done in isolation from technological development elsewhere. The problem here is not merely catching up with the advanced countries; rather it is managing ethno-science with modern science. Thus, science and technology policies in Africa should strive to strike a balance between indigenous technological development and imported technology. The aim should be the achievement of a technological pluralism in which foreign technology (including frontier technologies) can be utilized side by side with traditional technologies. From a scientific and technological perspective, Africa must rely for solving its present problems more on the available array of technologies and existing institutions and mechanisms than on the development of innovations. Modifications of the present institutional setting, innovations in, and diffusion of, new technologies are costly and time consuming, and often with uncertain results. Institutional changes also take time to materialize, especially when change is hindered by those who are concerned more with protecting their turf than with societal progress.

The question, therefore, is how to choose from the available set of technologies, the ones that can contribute most to the solution of today's African problems without creating rigidities that could impede the adoption of emerging technologies? In this connection, African scientists are faced with the responsibility of assessing the potentialities of those emerging technologies not only to ascertain their applicability to the African condition but also to ensure participation in the process of their development. In recent years, the idea that mankind is at the turning point of a new 'technological revolution' similar to the industrial revolution of the 18-19th Century has gained more and more followers. This revolution is information and scientific intensive. The information revolution is no longer science fiction, it is a present day reality with a direct impact on the lives of the African citizens in its two forms: computer and telecommunications technologies. However, its development and application are largely concentrated in the industrialized world and grow at the rate of 20 per cent annually. The information revolution requires a quantum change in each country's education and training systems. Many of the newly emerging technologies — particularly informatics, microelectronics and biotechnologies — are 'natural-resources-augmenting', meaning that they help expand supply of natural resources that can be exploited for economic purposes, particularly those needed for the satisfaction of urgent basic needs. And many of these new core technologies[5] do not require large capital investments and they can develop in decentralized systems, thus facilitating the process of rural development. In addition, they are not necessarily energy-intensive, and in particular not oil-intensive. They are rather material-saving and because their reduced wastes permit a more integral use of raw materials, they have their positive environmental impact.

Equally important is the fact that the new emerging technologies can be applied for the revitalization and upgrading of vernacular or traditional technology and therefore, can be assimilated by the population without major cultural conflicts. This suggests that a policy oriented to the merging of new and traditional technology could help avoid the negative aspect of the technological dualism that has so far characterized transfer of technology from the industrialized to developing countries. Thus, the idea of technological blending, or merging of new and traditional technologies, implies a completely different approach to technology policy and planning. The objective should no longer be 'bridging the gap' between technological advanced areas and those presumed to be backward. It also would require a long process of socioeconomic adjustment and change. The policy of merging implies the possibility of a technological 'jump' in which it would be possible to benefit from the advantages of new technologies without having first to undergo fundamental investments in technological infrastructure, as it was necessary with the exclusively imported technologies. The prevailing policy of importing technology condemns the developing African countries to perpetual backwardness.

African countries should therefore, strive to take part in the development and application of new frontier technologies. Increasing efforts in these technologies are being undertaken by some developed countries in order to

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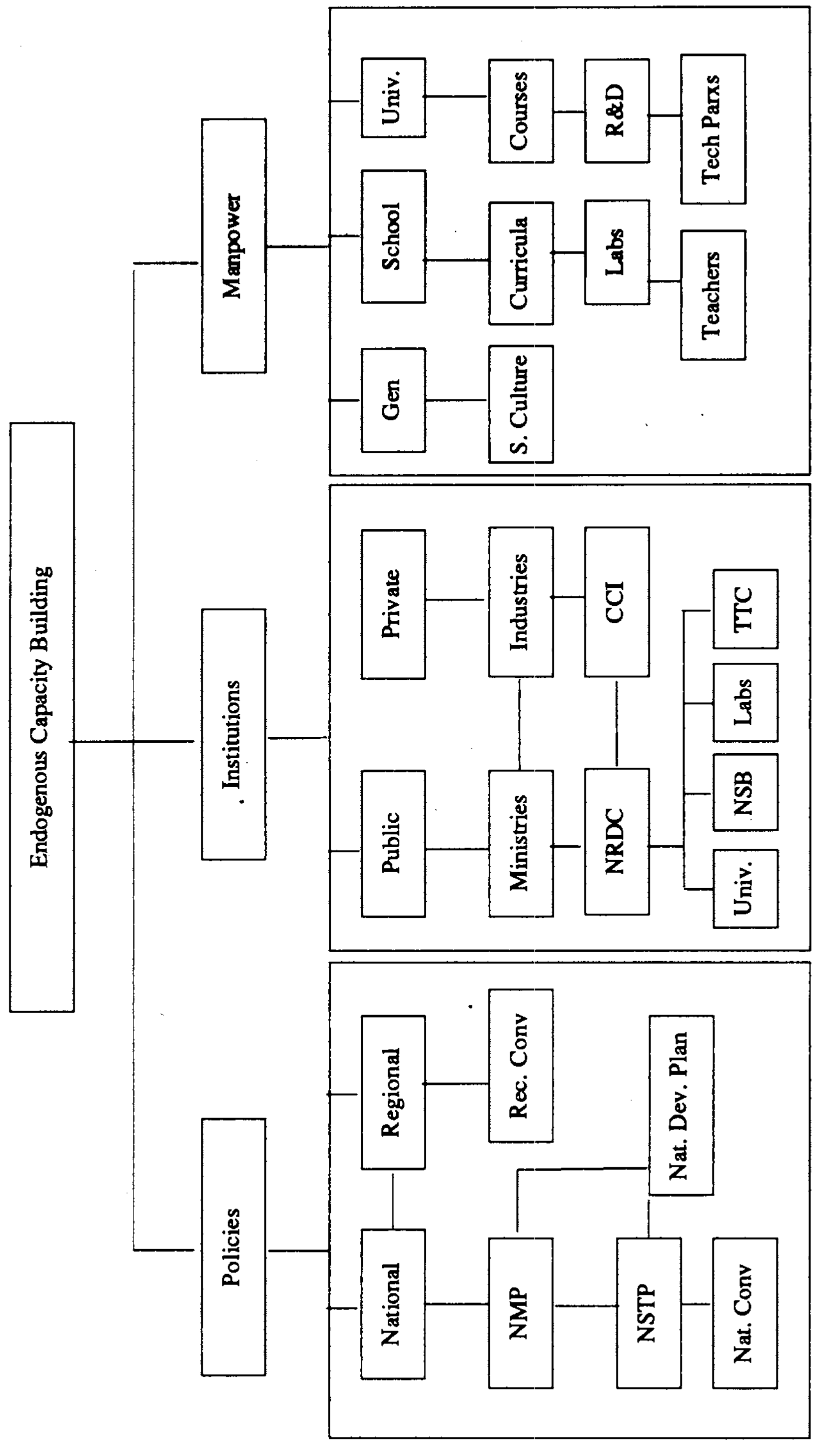
5 The new core technologies can be subdivided into three categories: (1) Microelectronics which include computer integrated manufacturing industry, consumer electronics services industry, office automation; (2) Biotechnology which includes food processing industry, pharmaceutical industry, agrochemical industry, fine chemicals, petrochemical industry, waste processing industry, niomedical materials, aeromedical materials, aerospace industry and textile industry; and (3) New materials from aerospace, telecommunication and transport industry; metal/steel industry and semiconductor industry.

redefine international competition and achieve comparative advantages (e.g. Japan vs USA). But these efforts are no longer limited to developed countries; several developing countries have undertaken aggressive policies to participate in the development of those technologies (e.g. Brazil), particularly with a view to increasing productivity and reducing costs in export-oriented activities in order to retain old, or capture new markets. This is true even in traditional sectors like textiles and leather (e.g. Taiwan) which are, currently being reactivated in industrialized countries. African countries cannot remain indifferent to all this revolution and remain passive importers of technologies. They have to be active participants in its development in order to benefit from 'learning by doing' and reducing, in the process, their technological dependency. The merging of new technologies with conventional and traditional technologies is an approach that could permit a quantitative and qualitative jump by-passing, in some cases, intermediate steps.

Conclusions

A science and technology culture is still relatively underdeveloped in Africa. Whatever science and technology there are and that have been brought from outside, have stayed within a small elite who have found it difficult to share their knowledge with the masses. This low level of science and technology culture does not popularize basic concepts and make the general masses appreciate the marvels of modern development. The development of manpower in the area of materials is a long-term process and one has to start from the bottom. It requires a strong political will backed by policies and plans, the involvement of the private sector and stakeholders in the economy, adequate financial support, appropriate incentives through legislation to all concerned, institutional structures, and co-operation at the sub-regional and regional levels to optimise the scarce resources available. The popularization of science and technology using all available modes of propagation — folk dramas, folk songs, music, science clubs, audio-visual channels, newspapers, exhibitions, popular talks, seminars and conferences, etc., has to be the basis for such an S&T culture. Thus, cultural dimensions have to be integrated in all S&T programmes and projects in order that they can be effective.

Annex Figure IA



Annex Table 1A: Science and Technology Policy-making Organs in African Countries - October 1986

	Ministry of Science or	Science Ministerial Science	Multisector body for Coordinating Scientific Planning	Coordinating Bodies for Scientific Research: Natural Sciences Research	Agricultural Research	Medical Research	Nuclear Research	Indus. Research	Env. Research
Algeria	*		*		*			*	
Angola									
Benin	A	A	*	A	*	*		*	X
Botswana			A	A				A	
Burkina Faso	X	X	X		*	X		X	
Burundi	A			A	X			X	X
Cameroun	A	*	*	A	*	*		*	
Cape Verde									
Cent. Africa Rep.	A	X	*		X				
Chad	A		*	A	X	A			
Comores									
Congo	A		*	A	X	X		X	
Côte d'Ivoire	*	X	*	X	*	X		X	X
Djibouti									
Egypt	*			*	*	*	X	*	*
Equatorial Guinea									
Ethiopia			*	X	*	X		X	X
Gabon	X	X	X	X	X			X	X
Gambia									
Ghana		*	*	X	X	X		X	X
Guinea	*	X	*	X	X	X		X	X
Guinea Bissau									
Lesotho									
Liberia		*		X	X	X		X	
Libya Arab Jam.		A	X		X	X		X	
Madagascar	X		*	X	X				X
Malawi	A		X	X	*		A		
Mali	A	*	X	X	*	X		X	
Mauritania									
Mauritius									
Morocco	A		A		*		*		
Mozambique									
Niger	A	*	*	X	*			X	
Nigeria	A	*	*	*	*	*		*	
Rwanda	A	X			X				
Sao Tome & Principe									
Senegal	A	*	*	X	X	X		X	X
Seychelles									
Sierra Leone			A		A				
Somalia			A						
Sudan	A	*	*	A	*	*		*	X
Swaziland									
- Tanzania	A	*	*	X	X	X		X	X
Togo	X		X	A	X	X		X	X
Tunisia	*	*		X	X	X			
- Uganda					A			A	A
Zaire	A	*	*	X	*	X	*		
Zambia	A	*	*	A	*	*	*	*	X
Zimbabwe	A								
Total	27	20	28	25	32	21	4	25	15

Source: Compiled from Atul Wad, and Radnor (1983) Science and Technology in Africa. Priorities and Implications for International Cooperation, North Western University, Evanston, Illinois, U.S.A.
Unesco: Comparative Study on the National Science and Technology Policy-Making Bodies in the Countries of West Africa. Science Policy Studies and Documents No. 58, Paris, 1986.
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Note: 1. X indicates institution which existed before 1979
2. * indicates institution which existed in 1973
3. A indicates institution existing after 1979.

Annex 2A: Classification of countries according to the number of scientists and engineers engaged in R&D activities per million population and R&D expenditure an percentage of GNP* (for 1980)

R&D Expenditure as % of GNP	< 50	50 - 99	100 - 499	500 - 1999	> 2000
> 2%				United Kingdom	Bulgaria* (1) Lod. Rep. Germany Hungary* (1) Israel (Japan (1) Switzerland USA (1) USSR* (1)
1 - 1,9%				Austria Canada (1) Danemark France	Australia Belgium Finland Netherlands (1) Norway Poland* (1) Rumania Sweden
0,5 - 0,99%		Côte d'Ivoire Madagascar Senegal Zambia	Cameroun Egypte Togo		
0,2 - 0,49%	Burkina Faso Chad Nigeria Sierra Leone United Rep. Tanzania	Kenya Liberia Morocco Swaziland	Algeria Congo Ghana Mauritius Sudan Tunisia		
less than 0,2%	Angola Benin Burundi Central Africa Republic Ethiopia Gambia Lesotho Libyan Arab Jam. Malawi Mali Mauritania Mozambique Niger Rwanda Seychelles Somalia Uganda Zaire	Botswana	Gabon		

Number of scientists and engineers engaged in R&D activities per million population.

Source: Extracted from 'Estimate World Resources for Research and Experimental Development, 1970-1980, UNESCO, 1984 (CSR-S-17)

* In percentage of net material product (NMP)

(1) not estimated.

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