DEVELOPMENT OF A VIRILE ENGINEERING INFRASTRUCTURE THROUGH ENDOGENOUS SCIENCE AND TECHNOLOGY (LOCAL CONTENT)

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Introduction

Every nation needs to harness her human and material resources for the development and growth of her citizens and her environment. These resources are nothing if value is not added to them. The value-added to the resources endowed to nations by God is the difference between the developed and underdeveloped nations of the world. Most under-developed economies have natural resources but they are not able to develop the technologies required to add value to these; thus they remain in a vicious circle of poverty.

It is in order to stem the tide whereby most of the world's population lives in abject poverty and a few of the world's population swims in wealth and opulence that the United Nations declared the Millennium Development Goals (UN-MDGs) in September, 2000. In the UN-MDGs, 189 nations pledged to achieve the following by 2015:

- eradicate extreme poverty and hunger;
- achieve Universal Primary Education;
- promote gender equality and empower women;
- reduce child mortality;
- improve maternal health;
- combat HIV/AIDS, malaria and other diseases;
- ensure environmental suitability; and
- develop a global partnership for development.

The present administration at the federal level has been making efforts to achieve these goals. These efforts are anchored on the reform of different sectors of the economy in such a way that the economy will be driven more by the private sector and less by the public sector. In this dispensation, the public sector only serves to provide the enabling environment for sustained economic growth. In addition to regular public service line ministries and parastatals, different programmes are currently being implemented including the National Economic Empowerment and Development Strategy (NEEDS) and New Partnership for African Development (NEPAD) to create the environment required for a private-sectorled economic growth.[1]

The success of these laudable programmes depends on the existence of a viable infrastructure base which on the other hand depends on the existence of a sustainable and functional engineering infrastructure base which will provide the needed machinery and facilities for a production based economy.

Infrastructure: What is it?

For a nation to develop, it must have an infrastructure on ground. The word 'infrastructure' connotes different meaning to different people. Infrastructure, most generally, is the set of interconnected structural element that provide the framework for supporting the entire structure. It usually applies only to structures that are artificial. The term is used differently in a variety of fields; perhaps the single most well-known usage is in economics, where it refers to physical infrastructure such as buildings and roads.

The term is often used very abstractly. For instance, software engineering tools are sometimes described as part of the infrastructure of a development shop, and the term infrastructural capital in economics may be overly broad, as it includes a range from clothing to a continent-spanning canal system. This term can overlap with the notion of internal improvements and public works.

The term is used most often in an urban planning context to denote the facilities that support specific land uses and built environment. Typically, infrastructure in the urban context denotes two general groups of support systems: transportation modalities (roads, rail, etc.) and utilities. These typically compose both public and private systems, and some ambiguously held in common.

Infrastructure may also refer to necessary municipal or public services, whether provided by the government or by private companies. If provided by nature, e.g. the flow of a river, they are called nature's services and are defined (at least in economics) as the product of natural capital. This may be augmented or directed by infrastructural capital, e.g. a dam or canal or irrigation ditch. In general what is called **infrastructure** tends to be much embedded in the natural landscape and cannot be moved from place to place. Even municipal services rely necessarily on fixed locations, e.g. fire stations in central positions in a city, radio towers on tall buildings, etc.

Infrastructure (in the civic sense) includes: transport (roads, highways, railroads, public transport, airports, ship transport such as ferry and barge, bike paths, sidewalks, greenways); public utilities (electricity, natural gas, coal delivery, water supply, sewers, telephone service, radio and television broadcasts); public services (fire service or fire department, flood protection, police protection, waste management); national services (defense, monetary systems or currency, including the minting of coins, and printing and backing of banknotes, postal system, frequency allocation, i.e., electromagnetic spectrum management for broadcasts (terrestrial and satellite)).

'Soft Infrastructure' is a term that denotes institutions that maintain the health and cultural standards of the population. Principally, this refers to public education, public health systems including public hospitals, public libraries, social welfare.

In short, 'infrastructure' refers generally to 'those manpower and physical structures and installations which a country establishes for the purpose of facilitating its agricultural, industrial and commercial production, rendering social services and maintaining the security of the community'. These include transportation infrastructure, manufacturing infrastructure, communication facilities, utilities supply, housing, power, education and healthcare facilities, firefighting systems, systems for the maintenance of law and order, etc.

However, when we talk of engineering infrastructure, the development of which is the mandate of NASENI, we are talking about infrastructure to fast-track home-initiated and home-grown industrialization achievable through local machine-designs and machine-building capabilities, resulting in general provision of such capital goods and equipment which encourage the proliferation of viable small and medium enterprises. When the economics talk about building of roads, development of utilities, provision of water systems, and other physical infrastructure, the bottom line is the development of the basic infrastructure to make all of that possible. The provision of such basic infrastructure is a measure of the economic and manufacturing growth of a nation. For example, every industry is composed of unit operations. Each unit operation is an equipment that is designed and produced to carry out a particular function. It is all these functions put together that result in the manufacture of the particular product.

Government must therefore provide the enabling infrastructure to support science and technology sector which is aimed at manufacturing and in research and development. Science and technology funding by government is a necessary and obligatory expenditure in any society desirous of rapid economic growth.

Current state of the Nigeria's infrastructure

In discussing the current state of the Nigeria's infrastructure, we should give credit to the present administration. Much is being done but because of the decay over the years, the efforts are still a far cry from where we are supposed to be. Let me just take a look at the history of some sector of our economy in an attempt to discuss the current state of our infrastructure.

Power

The first generation plant was established in 1898 at Lagos to serve the colonial administration. This was followed with several isolated power stations to which various towns in the federation tied to their loads. The creation of Electricity Corporation of Nigeria, ECN, in 1950 brought about strategic programmes at establishing a power industry which is sound, operational, reliable and flexible to manage. The Niger Dams Authority, NDA, was established in 1962 and by 1968 the government built and commissioned the Kanji Hydro Station. The ECN

built more generating stations (thermal and hydro) and transmission lines to link the generating stations in a grid system to towns and cities. In 1973 ECN and NDA were merged to form the National Electric Power Authority, NEPA, and up till now they are still responsible for the generation and distribution of electricity.[2]

Before the reform of the Nigeria electricity sector, there were eight power stations including the moribund Afam Power Stations with an installed capacity of 5,920 MW. The available capacity of less than 3,000 MW and the demand for power of 9,700 MW means that most Nigerians will continue to go on without electricity.

The reform in the electricity sector has opened up the sector and this has encouraged the participation of the private sector in the generation and distribution of power. The independent power producers are now building power stations; some have been commissioned while the others are in various stages of completion. Government however did not leave everything in the hands of the private investors as it has embarked on building of power stations which on completion will boost the power available for distribution. It is unfortunate that all the billions of Naira that have been sunked in NEPA have not been able to guarantee Nigerians near regular supply of power. Part of the problems can be traced to lack of basic infrastructure and maintenance culture.

Petroleum

A lot of Nigerians and factories have settled for electricity generator as the alternative means of generating power. Adding their demand for petroleum products and that of the large number of automobiles in the country, thus, the quest for refined petroleum products is on the increase. However, Nigeria, the sixth largest oil producer in the world has only four refineries. These refineries are either not producing at all or are producing far below their installed capacity. The direct result of this sorry state of the petroleum down-stream sub-sector is the continuous importation of refined petroleum products.

Nigeria is in this pathetic power and energy condition today due to the neglect of the sector by past administrations. However, the present government has started the reform of the down-stream sector; allowing the participation of the private sector in the down-stream sub-sector of the economy. The administration has recognized that per capital energy consumption is an index of the living standard of the people of Nigeria.

Transportation infrastructure

Transportation is a very vital infrastructure needed for the growth of the economy. The ease with which people and raw materials move from one part of a country to the other speaks volume about the economy of that country. Even though there are different types of transportations like rail, water, air and pipeline, much emphasis is on transportation by road. Just like other infrastructures that depend heavily on proper government planning and the state of technology, the state of transportation infrastructure in the country has been in a state of neglect and this has impacted negatively on the state of development of the economy. Some of these types of transportation and their states in the country are:

Land transportation

Land transportation consists of roads, vehicles and motor parks among others. Of all these constituent components, the most important is the road. This is because road transport consists of about 95% of all surface transport in Nigeria today with total national assets (200,000 km of federal, states and local government roads) of over three trillion naira. Despite these huge assets, the annual budget allocation for maintenance and the importance of the roads to the land transport, only less than 27% of the road network in Nigeria is in good condition.[3] The state of the roads in Nigeria is bad and is becoming embarrassing to all stakeholders. This challenged the Nigerian Society of Engineers (NSE) and the Federal Ministry of Works to organize a workshop on 'Making Nigerian Roads Motorable' at the Hilton in Abuja on the 13th January, 2006. In that workshop, recommendations were made that the private sector be included in the building and maintenance of the roads, toll gates be reintroduced, road funds should be established and road management institute be established amongst others.

Air transport

Towards the end of the year 2005, Nigeria suffered three unfortunate air disasters. The Belview Airline that crashed in Lisa Village claimed over 100 lives and for the Sosoliso Airline that crashed in Port Harcourt, over 50 school children were amongst the passengers. There was also an incident in Kaduna where all the crew and passengers on the plane died. Beside the three accidents of that year, there was also several other incidences of aircraft veering off the runway on landing or overshooting the runway or aircraft running into cattles or birds on

landing. Nearly all the accidents and incidences that occurred in the aviation industry in Nigeria are attributable to the very old aircrafts in the fleet of the operation and the obsolete navigational and landing equipment and the compromising attitude of some the personnel in the aviation monitoring and enforcing agencies.

The accidents have brought the issue of the dilapidated and obsolete navigational equipment to the front runner. The findings of the commission of enquiry into the activities of the aviation industry revealed the rot in the industry and government is going all out to correct the rot. The old aircrafts in the fleet of airline companies are being changed and the equipment and facilities are being updated.

Transportation by rail

Transportation by rail was the traditional method of transportation during the colonial era and the period immediately proceeding 1960. Even though the rail-track of narrow gauge, meant for transportation of raw materials from the hinterlands to the ports for export, but with proper maintenance it was also used for moving people and goods from one part of the country to the other during the colonial era and after. The rail as it is now is in a sorry state. There is hardly anything functional with the rail-system under the Nigerian Railways that is now moribund. Corruption and mismanagement that was the hallmark of the period between 1980 and 1999 saw to the death of the rail-system in Nigeria. The rail-system can be revitalized and wider rail tracks laid in new places in addition to introducing electric train to make transportation by rail more efficient and reduce the pressure on our roads and by implication reduce accident rate on our roads.

Pipeline transportation

Pipeline transportation became popular after the discovery of oil in Nigeria. Pipeline transportation is mainly for transporting oil in the country, but there are countries where pipes are used for transporting gases to homes and industries just like water pipes. The use of pipe for transportation in the nation is still underutilized. The problem of pipe vandalization is a major battle that is being fought in recent times.

Water

The relevance of water as an infrastructure cannot be over-emphasized. The relevance is more felt in the industries where water is used for production; in fire fighting services; and at home for cooking, drinking and other domestic uses. According to World Bank, Nigeria's total water resource available/capital (m^3) including water flow from other countries is 2,260 m^3 and the annual use as the percentage of the total is 1.4 (1980-2000). This shows an under exploitation, operation, control and management of the abundant water resource. Water supply especially from the public mains has been unreliable over the years. It is even worse in the villages where people have resorted to unclean water for domestic uses and other applications. In the towns where there are more concentration of industries, the problem is usually that of exploitation and efficient distribution of water to places where they are needed. Some of the problems affecting the generation and distribution of water are:

i. Lack of enough resources to change ageing water generation and distribution equipment.
ii. Shortage of dedicated, efficient and properly trained manpower to man this equipment.
iii. Misappropriation and in some cases outright embezzlement of funds meant for the maintenance of the few available equipment.
iv. Indiscriminate digging of ground for construction purposes that in most cases leads to destruction of water distribution of pipes.

The availability of adequate water resources in the country shows that opportunity abounds if the resource is well utilized. To ensure proper utilization of water resources and management of the available water resources to meet industrial and domestic uses, there is need for privatization of the generation and supply of water resources. This is to ensure efficiency and judicious utilization of funds meant to see to the growth of the supply and generation system.

Agriculture

Agriculture was the main stay of the nation's economy before the discovery and commercial exploitation of oil. Even though it was not a mechanized type of agriculture, there were indicators that being the major revenue earner for the country then it was only a matter of time before the agricultural practices was partially mechanized. The plan however did not see the light of the day. With oil boom era, able-bodied men that were the backbone of

subsistence agriculture left the farms and villages to pursue non available white collar job (civil service jobs) and left subsistence agriculture for our old parents.

Mechanized agriculture is an easy type of agricultural practice where machinery and other farm implements that make work easier, faster and produce greater yield. This is because of the advancement in technology and better infrastructural facilities needed for better agricultural output. But unfortunately enough, the infrastructural facilities needed to boost agricultural yield are non available. This is mainly due to low investment in science and technology. With mechanized agriculture ably supported by good infrastructure, high population normally required for subsistence agriculture will not be necessary anymore. Better infrastructure that will contribute to greater agricultural practices can be better achieved if there are more investment in science and technology that will produce tools and implements needed for mechanized farming.

Telecommunication

The information-age has made technology, particularly Information and Communications Technology (ICT), indispensable. Nigeria is often identified as the fastest moving economy and one of the most advanced ICT market sectors in the Africa. It has the largest population in Africa, also making it an attractive and big market. Telecommunications infrastructure is particularly important, because of its far-reaching impact. Telecommunication infrastructure remains one of the major issues affecting technology deployment required for growth and development in Nigeria. There has however, been massive improvement in infrastructure over the past few years. Nigeria has certainly left the telecomm state where there were only a few dial-up e-mail providers and internet service providers (ISPs) and when Nigerian Telecommunications Limited (NITEL) was the only telecommunications operator. It was a dark era characterized by slow Internet links, poor service, high cost, lack of infrastructure and an unprogressive telecoms monopoly. Things have certainly changed. Deregulation of the telecommunications sector led to the introduction of major Global System of Mobile Communications (GSM).

The GSM revolution began in August 2001 and changed the face of Information and Communications Technology in Nigeria. But the picture will not however be complete without mentioning the Private Telephone Operators (PTOs) and other landmarks such as the licensing of Globacom as Nigeria's Second National Operator (SNO) as well as the licensing of 22 fixed wireless operators. Since the GSM launch, mobile telephony has rapidly become the most popular method of voice communication in Nigeria. Growth has been so rapid that Nigeria has been rightly described in various fora as 'one of the fastest growing GSM markets in the world'. Indeed these developments have been truly explosive: today Nigeria has about five million mobile lines and about one million fixed lines, compared with just about 450,000 working lines from NITEL three years ago.

But Nigeria's telecom infrastructure story and growth has not been due to GSM alone. For example, GSM doesn't have much to do with the upsurge in internet usage and access. In essence it is the combined activities of Nigeria's telecoms providers. GSM, FWA, PTOs, telephony and VSAT operators and NCC's regulatory efforts that has led to increased competition and availability of a wide range of voice, data and internet applications and services. The improvement in the telecom situation in Nigeria has made significant impact in all sectors — commerce, social and educational. Although most of the impact is presently felt only in the urban centres, NCC has announced plans to ensure the telecomms revolution also touches the rural populace. As noted by one of the International Telecommunications Union (ITU) publications, there is "a direct correlation between access to telecommunications, economic wealth, and social development".

The telecomms boom has resulted in greater usage of internet technology, growth and availability of cyber cafés, increased internet provision by ISPs and PTOs, increased communications services (mobile telephony, e-mail, VOIP), reduction of internet costs, online information gathering and research, e-learning, Internet business opportunities, online advertising opportunities as well as developments in e-banking. Growth has been phenomenal because Nigeria's size is massive and Nigerians have been starved of such access for decades. A kind of 'Thank God the drought is over' experience. So, while there might be an IT or telecomms downturn in the rest of the world, the ICT sector in Africa, especially in places like Nigeria continues to boom. With the opening up of the telecoms space further dramatic growth is expected as service and reliability demands increase. However, in-depth penetration and qualitative infrastructure growth is critical.

Engineering infrastructure

Engineering infrastructure is defined as those capabilities and physical plants which are required to enable a prolific machine design and production to take place. Prior to urbanization people lived simply; lives with everybody depending more or less on nature for survival. All that has changed with thousands, sometimes

millions, of people living together in a city sharing facilities. In most cases, these facilities have to be shared within the city and sometimes amongst cities. For the effective running of the cities, a functional infrastructure must be provided. For example, adequate provision must be made for transportation infrastructure to include land, sea and air. Furthermore, land infrastructural development will not be functional without roads, vehicles, motor-packs, etc. For sea or water transport, there must be waterways, seaports, ships and vessels, etc.

In providing power infrastructure, facilities such as generating stations, transmission lines, distribution lines, switch gears, transformers, petroleum extraction and distribution, etc, must be provided within and amongst cities. Educational infrastructure must provide schools, teachers, laboratories, libraries, etc. the health infra-structure must include hospitals, health workers, drugs and equipment, etc. Other infrastructures that must be provided include agriculture, social service, etc: The social service must provide adequate security and a judicial and legislative frame work for effective running of the city.

The existence and functionality of these infrastructures in a nation determines her level of development. Thus, the developed nations of the world are noted for the high-level of their existence and functionality of their infrastructure. These nations have, over the years, developed their infrastructure base to a level where they are abundantly available and effectively functional. Attributed to this is the fact that they have the resources and the zeal to develop and sustain their infrastructure. The resources they utilize are not only monetary but mostly in terms of the skilled personnel, machinery and engineering materials required for building and maintaining the infrastructures. The utilization of skilled personnel, machinery and engineering materials could be referred to as engineering infrastructure.

Development of engineering infrastructure in Nigeria

Nigeria depends heavily on imports and this has drastically affected our infrastructural development. Our dependence on the developed nations has inhibited the evolution of our own engineering infrastructural base. Our complete and absolute dependence on the other countries engineering infrastructure has kept our nation in an aggravating dept trap and only means of escape is the urgent establishment and sustenance of our own functional engineering infrastructural base. We must all accept the fact that Nigeria must take deliberate steps to establish its own capability in the mass production of the equipment and machinery, which its growing economy requires in large numbers.

However, while it is granted that the ready availability of machinery is what makes the difference between high productivity and sustenance, between reliability and dependence and between wealth and poverty, there are thousands of machinery types which a modern economy utilizes. 'Obviously, the active involvement of government in the establishment of an engineering infrastructure does not mean that government should be actively involved in the mass production of this innumerable number of types of machinery'.[3,4]

This role of a functional engineering infrastructure base are numerous and must include amongst others: providing the infrastructural base on which industrialization and development can thrive; development of raw materials for industries; new products development; innovations for improvement of industrial fortunes; providing the engineering infrastructure for the industrial sector; providing machines and spare parts required by industries; providing the equipment and machines required for rural development activities; evolution of domestic technology capability in manufacturing; developing skilled human resources and relevant manpower for the industrial sector; and conceptualization and construction of the different infrastructure required for development activities.

In order to actualize these roles, government has actually set up a good research and development system for development of engineering and technology in the country. The size of the research and development system work going on in the system in Nigeria can be assessed by the recent publication of profiles of selected commercialisable research and development results and publications.[5,6]

There are at least 66 different research and development institutions, excluding tertiary institutions described in those publications with different mandates. One of the institutions devoted to the development of engineering infrastructure (EI) is the National Agency for Science and Engineering Infrastructure (NASENI). The agency was established in 1992 and later as a parastatal under the Federal Ministry of Science and Technology (FMST). It was set up to execute all aspects of the science and engineering infrastructure policy of the Federal Government of Nigeria.[7]

NASENI's mission is to establish and nurture an appropriate and dynamic science and engineering infrastructure base for achieving home initiated and home sustained industrialization process through the development of relevant processes appropriate local machine design and machine building capabilities for capital goods and equipment manufacture for job creation, national economic well being and progress. Priority attention

is given to seven broad economic areas namely; Engineering Materials, Chemical Materials, Scientific Equipment, Electronics, Engineering Accessories, Power Equipment, Hydraulic and Pneumatic. Machinery and Engineering Tools. There is an engineering design centre which was setup to develop design capacity relevant to these broad economic areas.

The strategy for using NASENI to develop a functional engineering infrastructure in Nigeria is illustrated in the Figure below.

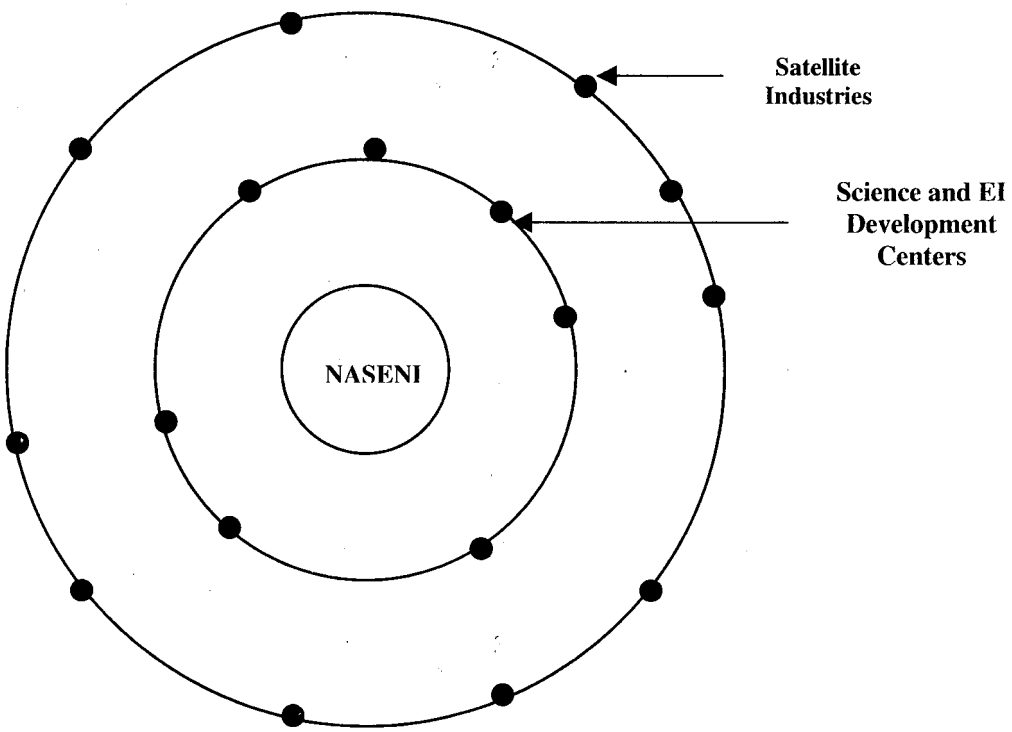

Figure 1: Strategy for a functional engineering infrastructure.

Manufacturing technologies are developed and tested in pilot plants at Science and Engineering Centers. Secondary plants (satellite industries) owned by the private sector spring up from the work of the Development Centers. Such industries mass-produce the technologies or the capital goods developed at the development centers. The tertiary plants (private sector) would in time spring up to provide supplies to the secondary plants. At present, NASENI operates seven development centres across the country.

These centres are: Scientific Equipment Development Institute, Enugu (SEDI-E); Scientific Equipment Development Institute, Minna (SEDI-M); Center for Adaptation of Technology (CAT), Awka; Engineering Materials Development Institute (EMDI), Akure; Hydraulic Equipment Development Institute (HEDI), Kano; National Engineering Design Development Center (NEDDEC), Nnewi and Power Equipment and Electrical Machines Development Center (PEEMADEC), Okene. Two other centres, the Heavy Machinery and Equipment Center (HEMEDEC) and Chemical Equipment and Machinery Development Centre (CEMADEC), are planned for Bauchi and Port Harcourt respectively.

The role of NASENI should not be confused with that of other institutions set up to develop prototypes of machines and processes. Ours is to ensure that the engineering infrastructure required translate the innovations into commercial capital goods are available and functional. When these are developed, they are transferred to the private sector. The model used is the hybrid technology development and diffusion of the demand pull model and the technology push model.[8,9]

Engineering infrastructure for national development: Problems and opportunities

As enumerated above, Nigeria cannot develop without an adequate and functional engineering infrastructure. So, it goes to say that the development and sustenance of a sound and functional engineering infrastructural base is

actually the development of Nigeria. In the process of developing the engineering infrastructural base for the country, there will be problems which will generate opportunities.

Therefore, in order to develop the engineering infrastructure, all the differing stakeholders must take active participation. The role of NASENI is to provide the enabling environment for the stakeholders to grow; it's like NASENI being a tree while the stakeholders are the branches of the tree. Some of the aspects of the enabling environment which NASENI and the other stakeholders are currently pursuing or must pursue in future are discussed briefly below.

These programmes are designed to address the problems militating against the development and maintenance of a functional EI base for Nigeria. These problems have been discussed variously elsewhere to include:[10,11,12, 13 and 14]

- *Lack of political will to develop a grand vision for infrastructural development for the nation.* Various governments over the years have paid lip services to the development of infrastructure in the country. There is no consistent vision and mission in this area.
- *Lack of maintenance culture.* The few existing infrastructure are never maintained. Many of them have become an eye sore and a national disgrace.
- *Lack of participation by all stake holders in EI policy making process.* The Nigerian economy lacks a critical mass of relevant skilled manpower for engineering and technology applications. Government at all levels have not shown serious commitments in terms of resources towards creating the enabling environment for EI.
- *The non recognition and hence poor challenges for the few relevant manpower within the country.* The R and D system in Nigeria is characterized by inadequate funding, poor facilities and poorly motivated manpower. The scientists and engineers involved in R and D in our tertiary institutions are seen as radicals with little to contribute to the development of the country.
- *Poor linkages between R and D institutions and the industries.* Reluctance of industries to invite R and D institutions to solve their problems; and
- *Difficulties in commercializing R and D results.*
- *Absence of a technology culture in the society*
- *Very difficult and inconsistent economic environment for engineering operations.*
- *Poor power and utilities supplies.*

Reverse engineering programme

Many of the machines required for a functional EI are already in existence outside the country. In order to avoid attempting to re-invent the wheel, one option is to use reverse engineering to domesticate the technologies. This approach involves acquiring an imported machine, tearing it apart and 'redesigning it'. The redesign will include producing parts, drawing and manufacturing layout such that any fabricator or manufacturer can produce it. This concept has been successfully used to replicate and proliferate some machines within the NASENI family. At present work is in progress in using reverse engineering to reproduce the following machines: single axle tractor, vegetable oil expeller, potato processing plant, and interlocking brick making machine.

Industrial cluster programme

The role of industrial clusters in technology development has been acknowledged by many. In Nigeria, industrial clusters have been identified in a number of areas including Lagos, Ibadan, Kano, Kaduna, Onitsha, Nnewi and Aba.[12] A number of agencies of government and those of international organizations (UNIDO, UNDP) have been involved in assisting these clusters for further development. There is need for more work in assisting these clusters to achieve their maximum potentials. It appears that some of these clusters evolved on their own. Efforts need to be directed towards establishing more clusters in areas with the potential. The continuous development of industrial clusters is a sure way to develop and maintain engineering Infrastructure (EI).

Technology incubation centres and science parks

The establishment of viable Technology Incubation Centres (TICs) and Science Parks is another way of ensuring that a functional EI base emerges. Attempts have been made in the past to encourage the establishment of TICs but their performance has not been as expected. In order to revitalize the TIC programme, the Federal Ministry of

Science and Technology recently started a process for restructuring and revitalizing TICs in the country. Currently, there is a new Board for Technology Incubation which is now in charge of managing the existing TICs and establishing new ones. At NASENI, efforts are underway to establish a TIC which will be the avenue for commercializing technologies developed by the NASENI family and in fact other R and D organizations. Some state governments, including the FCT administration are also working towards establishing Science Parks.

Satellite industries programme

Closely related to the TIC concept is the satellite industry development concept. As noted earlier, satellite industries are supposed to spring up from the technological advancement of NASENI development centres. The idea is that private sector firms can establish new industries based on products of research from research centres. Such industries, of course require some incentives since most of the projects may not be immediately economically viable and may be high risk areas where entrepreneurs will be reluctant to invest in. Presently, efforts are underway, to establish "risk funds" where potential industrialists can draw from.

Promotion of local content in industrial machinery

Most industrial machinery in Nigeria are imported. This is because, at present, the engineering infrastructure required for producing these machines are not in existence. Efforts are therefore under way to have a sustainable system for encouraging a progressive increase in industrial machinery content. This will require an understanding with manufacturers and industrialists. Projects can start with local production of spare parts and gradually graduate into the design and fabrication of individual units of process lines and complete process lines. NASENI is already working with some industries towards achieving this goal.

Investment in emerging technology development

As Nigeria is battling with the development of what the developed world may regard as conventional technologies, the rest of the world is moving ahead with emerging technologies, thus further widening the technological divide. Therefore, as we struggle to develop the fundamental EI required for existing industries, we must work to establish the EI of tomorrow which are required for sustainable development and use of emerging technologies. These emerging technologies include biotechnology, ICT, Nanotechnology, Space and Satellite Technology, New Materials, Robotics, CAD/CAM, Virtual Manufacturing Systems, etc. Since these areas are capital intensive, there must be a special funding for the development of the EI required for these technologies. Currently, NASENI is working towards establishing such EI in the areas of nanotechnology, advanced materials, ICT components, CAD/CAM virtual manufacturing. Other parastatals of the FMST are also working to develop other areas.

Development programme for SMEs

For SMEs to fulfill their role as the engine of growth in the Nigerian economy, their operations must be technology driven. NASENI has articulated the draft policy on Development of Basic Technologies for Empowering SMEs. The policy among others is aimed at: promoting interactive actions and participatory programmes that will generate the emergence of relevant technologies and engineering infrastructure for the SME subsector and promote integrated R and D activities in support of the critical technological needs of SMEs. One of the projects under this programme include mineral processing, agricultural products processing, leather and wood processing, metal fabrication and casting, etc.

Proactive advisory role engineering infrastructural development

For Nigerian infrastructure to be developed and maintained appropriately there is need for different levels of government and major parastatals to be professionally advised in a proactive manner. NASENI and other parastatals of FMST offer high quality advisory service in the areas of appraisal, planning, execution and monitoring of major infrastructural projects. These include major projects such as TAM of refineries, LNG project, etc. Where the required expertise is not within the NASENI system, the plan is to engage the right type of skilled personnel from any where in the world.

Upgrading of 'mechanic villages'

In most major cities in Nigeria, the maintenance and repair of vehicles are now done at 'mechanic villages'. These centres which are usually designated by government are actually run by private car maintenance artisans. A

visit to any of these centres shows that most of them, in addition to maintenance of vehicles, are actually centres for engineering activities of different types. A closer look at the centers will also reveal the fact that most of the centers lack relevant machine tools which would have enabled them to do much more engineering work. It is therefore necessary to study and upgrade these villages into industrial layouts (or clusters) by providing the required facilities for productive engineering work. Similar work can be done with other 'technology villages' such as 'Computer Village' and 'GSM Village' in some cities.

Productive use of patents

There are over 40 million patents available over the internet. Most of them are already in the public domain. One of the mandates of NASENI is the assessing and re-packaging of information pertinent to manufacturing and process technologies as a service to SMEs. Such a methodology engenders innovation, quickens turn around time from ideas to the market place, thus allowing goods to be globally competitive.

NASENI programmes in emerging technologies

In addition to our role in midwife and collaborating with other stakeholders in actualizing the programmes listed above, NASENI is presently pursuing programmes aimed at developing and acquiring emerging technologies which will fast-track the pace of technology and business in this and next century.[14]

These programmes are:

Advanced manufacturing technology (AMT)

As Nigeria is battling with the development of what the developed world may regard as conventional technologies, the rest of the world is moving ahead with emerging technologies, thus further widening the technological divide. Therefore the focus of the Agency is a paradigm shift from the conventional manufacturing technology to an Advanced Manufacturing Technology (AMT). The ultimate purpose of Advanced Manufacturing Technology is to create wealth in Nigeria. Because of the importance the agency attached to this, a national workshop was held in April, 2006 in Abuja and papers were presented on some key areas of the AMT relevant to the national needs.

Nanotechnology

Nanotechnology is one of the emerging technology areas where Nigeria is lacking in expertise. It is classified in the same group as ICT and biotechnology. Already, the technology is being used in advanced economies of the West and South-east Asia, to create high technology industries in areas of electronics, medicine, development of new materials and space. Nanotechnology has been identified as one of the technologies of the future for Nigeria. This is therefore the time to key into the global network of research and development efforts. NASENI has been charged with this responsibility. The technology has potential applications in energy, medicine (diagnosis and treatment of diseases and environmental ills), nano-porus materials for water filtration, agriculture, electronic, etc.

It is also noteworthy that the President of the Federal Republic of Nigeria, Chief Olusegun Obasanjo, GCFR, has in the Science and Technology retreat held on the 17th August 2006, approved nanotechnology as the fourth leg of the national development policy on science and technology. The other three are biotechnology, information and communication technology and space technology.

A two-day workshop on Nigerian nanotechnology Initiatives was organized on June 8-9, 2006, by NASENI. At the end of the workshop sub-committees were set up to draw up a road map for the successful take off of Nigeria's nanotechnology and Advanced Materials Programme. The committees are in the following areas:

- Nanomedicine.
- Nanoelectronics.
- Nanostructured and nanoporous materials.

Each committee will meet, organize workshops and draw up the road-maps in their areas of jurisdiction. A business plan for nanotechnology is being drawn.

Nanoelectronic

Current efforts in nanoelectronics includes:

- A nanoelectronics laboratory is being put together at EMDI.

- In collaboration with Princeton University in the USA under the US-Africa Materials Initiative with Prof. Wole Soboyejo as the Program Director, nanodevices have been fabricated and characterised.
- The performance of new polymer based devices needs to be improved to be able to compete with silicon-based devices. One of such area under investigation by this presenter is Interface engineering specifically understanding of the adhesion properties of the physical contacts between the thin surfaces using AFM and other spectroscopic techniques.

Computer aided design and computer aided manufacturing (CAD/CAM)

One of the constraints to industrial machinery development in Nigeria is that most machinery producers are actually "road side" fabricators. Many a time, proper engineering drawings and design are not used. The result is that the machines are fabricated without using the best practices. Our programme is modern design facilities encourages the use of proper engineering design and drawings, which emphasizes good choice of materials, manufacturing layout and procedure and standardization of components and parts. That was, machines will have standard components, which can be manufactured by another entrepreneur. The overall effect will be lower cost of the machines, and good quality control. The headquarters and all our development centres are being equipped with CAD and CAM facilities. These facilities will be used for capacity building of SMEs in the use of modern design and manufacturing techniques to ensure that products meet international standards and can compete globally.

Virtual manufacturing laboratory

The process of machinery development is a tedious and unpredictable using the classical design and development approaches. With globalization and the ICT revolution, design, simulation and development of engineering systems are becoming more deterministic. NASENI headquarters is currently developing a Virtual Manufacturing Laboratory which will provide state of the art hardware, software and intellectual capacity for design, engineering simulation, and computer modeling of engineering processes, plants, machinery, spares. This will ensure rapid prototyping and hence reduce time and money required from moving from conceptual design to pilot scale plant development. The facility will serve as a national resource in engineering manufacturing and will be available to the R and D community in Nigeria as well as the SME sector, engineering firms and capacity development.

Rapid prototyping (RP)

The demand for rapid prototyping technology and related machines have been increasing steadily especially with the application in rapid tooling of machines for the production and the processing of advanced materials. RP is the creation of complex 3-dimensional physical models of a product directly from CAD drawing with little human intervention. Then the issue of risk and fear that are always expressed by the potential private investors/entrepreneurs will be put to rest as they will now have the opportunity to view such products on display as guaranteed and market ready.

Rapid prototyping technology helps industries to improve their design and product development activity by reducing design cycle time and eliminating error early in design stage.

Other areas of technological development

The agency has made giants strides in other areas of engineering infrastructure in the last one year.

Solar cell production

A joint venture project with a foreign partner is being executed to establish a solar panel manufacturing facility in Nigeria using the amorphous silicon concept and the use of Polymer electronics. The establishment of this solar cell manufacturing plant in Nigeria will result to the following applications amongst others: Domestic/street lighting, water pumping for irrigation purposes, power repeater stations and telecommunication booster station, power traffic light, small scale processing of farm products, and other applications in off-grid areas.

Solar lighting

The installation of the solar lighting system has been completed for the NASENI HQ. This provides light for the perimeter and other strategic areas of the HQ building.

These facilities are being extended to all our centres. For example EMDI Akure has been completed. Other centres will soon follow.

Establishment of mini-foundry in tertiary institutions

Although the Rotary Furnace was designed, developed and manufactured at EMDI, the Agency has assisted in distributing these to some higher institutions of learning across the country. Courtesy of ETF. The agency has undertaken so far the refurbishment and resuscitation of foundry facilities in 11 tertiary institutions. Similarly the agency has established mini-foundries by the provision of 100 kg rotary furnaces in 14 tertiary institution.

Primary science kit (PSK)

The agency started with the Primary Science Kit (PSK). PSK was developed and to ensure that the practical aspect of the Federal Ministry of Education's curriculum for primary science. A 1991 publication; *Core Curriculum for Primary Science*, was achieved.

For months, NASENI team of facilitators trained teachers in the six geo-political zone of the federation in the use of the kit for training pupils in Primary Science. At the end of each training workshop, 20 pieces of PSK was given to each participating state and FCT. This project is being planned for 50% of Nigerian primary schools in a scheme involving donors being coordinated by UNESCO, Paris. However, 25 more rotary furnaces are to be built in collaboration with ETF and distributed to institutions. NASENI has gone ahead to develop a science kit for the Junior Secondary Schools.

Data-banking of solid minerals using the md-10 mini-x-ray diffractometer

One of the necessary conditions for interesting investors in the solid mineral and gemstone sector in Nigeria is the detailed analysis of phase composition, including trace impurities compounds. As of now, this essential service is mostly undertaken in overseas' laboratories. However, as a consequence of acquisition and commissioning of a software driven mini X-ray Diffractometer at EMDI (NASENI) in Akure, these analyses are now being currently undertaken in Nigeria at Akure on the MD-10 mini X-ray Diffractometer equipped with software driven Standard Minerals Data Rules.

Development of austempered ductile iron (ADI).

Further to the development of foundry technology, EMDI has developed Austempered Ductile Iron (ADI) for the various applications usually requiring the service forged and high strength low alloy steel. From development work, a good aggregate of nodular graphite structure against flakes was observed.

Gordian Automatic Voltage Regulator (AVR)

Development and commercialization of a Gordian brand of Automatic Voltage Regulator (AVR) which regulates low/high voltage supply in order to safeguard and enhance the performance of domestic and industrial appliances.

Printed Circuit Board (PCB)

The PCB is an inexpensive electronic component that is used extensively everyday in Nigeria and in other parts of the world. It is the nucleus of all electronic equipment, instruments and gadgets because it is found in virtually every domestic, office and industrial electronic item such as voltage stabilizer, computer, blender, power supply unit, television, radio, video machine, amplifier, TV booster, photocopier, emergency lamp, telephone set, mobile phone, equipment for automatic processes, robot, avionics, communication satellite, to name but a few. It is of strategic importance to the development and growth of economies worldwide. Tlfis is so because the efficiency of any modern equipment has direct relationship with the sophistication of its electronics which, in almost all cases, is built on the PCB. There is no company presently in Nigeria that is engaged in commercial manufacture of PCB. Yet, countries such as South Africa, Libya, Egypt, Algeria and a few others in Africa manufacture PCBs indigenously and commercially.

Digital Information Display System (DIDS)

Electronic systems with artificial intelligence, which are based on single chip microcontrollers are designed and developed in C.A.T. This microcontroller uses the microprocessor as the central processing unit (CPU), and

serves as the brain of the system. Software (programmes) are developed, transformed into machine language and 'blasted' into the micro chip before interfacing with circuits.

Hydraulic and pneumatic equipments

Development and production of hydraulic pneumatic equipment and accessories, such as centrifugal water pumps, agricultural tractor hydraulic pumps, lift pumps, borehole hand pump, portable manual irrigation pump, micro hydro generator, etc.

Bioreactor

The design of a 5-litre capacity glucose syrup reactor which provides optimal conditions for the conversion of cassava starch to glucose via enzyme hydrolysis and determine the possibility of scaling-up the reactor to commercial size. The reactor could also be used for other microbiological research work and experimentation and most importantly serves as a fundamental teaching aid in biotechnology, pharmacology and microbiological research. It also has application in agricultural research.

Human capacity development in engineering design and development

In collaboration with United Nation Industrial Development Organisation (UNIDO), National Engineering Design Development Centre, Nnewi (NEDDEC) successfully conducted the following training programmes:

- Advanced Engineering Drawing and Design;
- Fittings;
- Computer Aided Design using the AUTOCAD;
- Foundry Technology (Ferrous and non-ferrous).

More than 20 different participants attended each of the training programme which was meant to develop engineering design and development for participants drawn from SMEs around Nnewi Engineering Cluster.

The Young Graduates in Manufacturing (YGM) and the Collaborative Manufacturing Scheme (CMS) continued to generate interest among stakeholders. The YGM program is designed as a refresher course in most vital areas that will inject design & manufacture confidence in the mind of young graduates. The CMS program initiated by NEDDEC was to collaborate with local machine shops & fabricators in both Nnewi and Aba, using their available infrastructure to manufacture component parts and equipment working hand in hand with our Engineers.

In-house and oversea training programme were undertaken on Autocad, Autodesk Inventor, Solid Works and other computer packages to prepare staff for the paradigm shift to advanced manufacturing and advanced material technology. NEDDEC won the bid to redesign and fabricate equipments for some other parastatals.

Conclusion

It has been shown that for Nigeria to achieve the UN-MDGs, there is need for a virile infrastructure which can only work if there is a virile Engineering Infrastructure (EI). The paper, having briefly discussed the current state of Infrastructure and EI in Nigeria, highlighted some strategies being implemented by NASENI and other related parastatals of government towards providing the enabling environment for a virile engineering infrastructure which is the basis for infrastructural development in Nigeria. This enabling environment will enable the private sector to develop and maintain a functional infrastructure base for sustainable growth of the Nigerian economy. A sustainable public-private sector partnership is imperative for this to occur. When a functional EI is in place, problems of building and maintenance of roads, airports, water, electricity, refineries and other infrastructure can be handled successfully by Nigerians.

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