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WHAT IS THE MANAGEMENT OF TECHNOLOGY ?

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A SEMINAR ON THE MANAGEMENT OF TECHNOLOGY

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By Titus Adeboye
Executive Director
African Technology
Development Link
Jitegemea Place, Jabavu Rd.
P.O.Box 47149
Nairobi, Kenya
Tel.: 254- 2- 71 25 56
Fax : 254-2- 71 06 54
E-mail: technlink @malone-net

INTRODUCTION

The 1998-1999 World Development Report of the World Bank represents a radical departure in development thinking by an institution that controls world development resources. Until that report was published, the World Bank's prescription for ensuring long-term growth had no role for technology. It is comforting to hear the World Bank president state that there is "the realization that economies are built not merely through the accumulation of physical capital and human skill, but on a foundation of information, learning and adaptation. Because knowledge matters, understanding how people and societies acquire and use knowledge – and why they sometimes fail to do so - is essential to improving people's lives, especially the lives of the poor" This, in fact , is the central issue in the Management of Technology, (MOT).

The Management of Technology is about how firms, entities, institutions or nations acquire, internalize, modify or adapt, deploy, innovate from and transfer knowledge, whether technical, managerial or organizational. The World Development Report classifies the knowledge issue into two: "Knowledge gaps" and "information problems". It treats knowledge gaps as those related to the acquisition of knowledge, the absorbing of knowledge and communication knowledge. It sees information problems in the realms of: processing the economy's financial information; increasing our knowledge of the environment; and addressing information problems that hurt the poor. There is uncharacteristically, an open admission that "most of the difficulties that developing countries face involve both knowledge gaps and information problems".

In the context of this welcome change by the World Bank, the World Development Report identifies specific roles for both governments and international institutions. It sees the role of governments as three fold: (a) narrowing the knowledge gap by: among other actions, adopting an open trade regimes, supporting lifelong learning and establishing a strong regulatory environment for a competitive communications industry: (b) providing information to verify quality, monitor performance, regulate transactions which will provide the foundation for successful market development, and (c) ensuring that other policies synergize with those designed to narrow the knowledge gap and provide information. On the other hand international institutions such as the ECA are enjoined to play three complementary roles. First, they are to provide public goods – or knowledge that has externalities that cut across countries . Second, they are to act as intermediaries in the transfer of knowledge. In this regard, ECA's new focus on networking and the dissemination of compendia of best practice and success cases seems right on target. Third, they are to manage the rapidly growing body of knowledge about development.

OBJECTIVES OF THE SEMINAR

It is in the light of this rather belated realization that we wish to focus this short seminar on the Management of Technology. Accordingly, the objectives of the seminar are:

(a) To create a greater awareness within ECA of the issues that concern managers of technology.

(b) To generate a better appreciation of the multi-disciplinary nature of the management of technology; and

(c) To suggest options for strengthening the in-house capacity of ECA to serve its member states better in the area of management of technology.

The rest of this paper is organized as follows: Section II defines the Management of Technology and its scope; Section III explores its multi-disciplinary nature; Section IV discusses the current status of MOT in ECA and how ECA could improve its provision of MOT services to its member States.

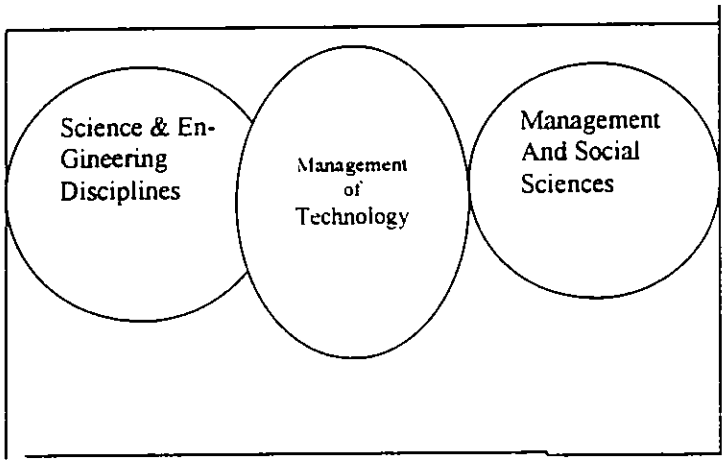
Section II : What is the Management of Technology ?

There are many definitions of the discipline of Management of Technology. It is good to examine a few of these in order to fully appreciate the critical issues it seeks to address. Khalil, T (1991), (I) defines it as a "cohesive interdisciplinary program that attempts to truly integrate the process of technological change with the strategic and operational aspects of decision making in running an enterprise." The Joint Universities, Polytechnics and Industry Education Research (JUPITER) (2) in the UK defines it as "a human skill, combining elements of engineering, science and management techniques, needed by organizations in order to fulfil technological capabilities and maximize strategic/competitive advantage in the market place". The National Research Council of the US, (3) on the other hand defines it as a discipline that "Links engineering, science and management disciplines to plan, develop and implement technological capabilities to shape and accomplish the strategic and operational objectives of an organization".

The various definitions can be synthesized in order to capture the central characteristics of the discipline and the broad sweep of issues that it encompasses. The management of technology deals with how firms, entities, institutions or nations acquire, internalize, modify, adapt , use, innovate from, and

transfer knowledge, whether technical, managerial, or organizational. It draws on many disciplines typically. A simple diagram has been used to illustrate this (4)

Figure 1.



Adapted from Bessant J. (1991) P.12

The Scope of the discipline derives from two broad traditions. The first is the " Life cycle model" which deals with the management of the process of innovation. The stages here include: idea generation, to experimentation and demonstration of technical feasibility (invention), to development, to commercialization, and further innovation. Abernathy and Utterback (5) are among the pioneers of this tradition. The second is the systems approach which treats different functions involved as systems that are inter-related (see Bignell *Et al* (6) and Waring A. (7) for detail discussions).

While the focus of the first tradition is the change process, the second deals more with the inter-relationships among the various change agents. Table 1. Lists the broad scope of both approaches.

Table 1. The Scope of Management of Technology

Life cycle Model	Systems Approach
Sources of ideas	Strategy systems
Research and development Invention	Manufacturing systems
Development	Human Resource Systems
Adoption and adaptation Diffusion Technology Transfer	Project Management Systems Financial Systems Management
Impact assessment	Information systems
Technology forecasting	

Taking the two approaches together it is easy to see the various issues that students of the Management of Technology typically study. These issues have been summarized by Collins et al (1989) as:

(a) The context of technology management
(b) Strategic Management of technology
(c) Technology project management
(d) Technological change and innovation
(e) Managing complex products processes and systems
(f) Professional teams in the Management of technology
(g) Technology forecasting, assessment, law and ethics.

These are spelt out in detail in annexure I. That annexure maps the entire terraine of MOT, and different training institutions choose from that menu.

III. The Multidisciplinary Nature of Management of Technology

The management of technology is multi-disciplinary in two ways. First its practitioners come from different disciplines. Second, the practice involves knowledge from many disciplines. This latter fact emphasizes its emergent status – the discipline is relatively new and emerging. When one examines the MOT field it becomes obvious that the field includes people from a wide range of disciplines. MOT subjects have been studied by architects, astronomers, chemists, and physicists. Practitioners have come from aerospace, electronic

and information sciences (communications, computer sciences, information systems, satellite systems) energy, environmental, food and agricultural, life sciences (botany, microbiology, molecular biology, zoology) biotechnology, mathematics, medical sciences (human and animal) optical engineering, physics (general, quantum mechanics, particle physics, nuclear physics, condensed-matter physics) psychology, sociology, economics, transportation, and the management sciences. Some of the leading scholars in the field of management of technology are historians (natural, science and social).

Apart from this broad sweep of disciplines of practitioners (which list is not exhaustive), the Management of technology draws its insights from many disciplines on any issue. A typical issue requires specialized inputs from different disciplines, and although managers of technology are given a broad exposure, their competence is usually of a managerial nature. They require specialized inputs from several disciplines in order to deal with specific problems or answer particular questions. Typically an MOT practitioner comes to the field with a particular discipline and he or she then gets training in particular ways of looking at issues which facilitates the process of accessing, acquiring, modifying and using knowledge.

Even within the MOT discipline there is specialization. The implication of this is that practitioners in this area, especially in research, work in multi-disciplinary teams. Research methods are also a hybrid (see Adeboye and Clark 1996) (8) for some of the problems of research in this area).

Formal training in the management of technology has been going on for several decades especially in the US, Canada and Europe. However, it is relatively new in other parts of the world, and almost non-existent in Africa. A recent survey shows that over 300 institutions world-wide offer degree or diploma courses in MOT, and nearly half of these are in the United States . See Table 2 for a listing of MOT training Programmes world-wide.

An Example

To illustrate the multi-disciplinary nature of MOT we can take the choice of technology for example. A technology manager, irrespective of his/her disciplinary background must understand certain basic issues about competing technologies. Typical questions he or she must learn to ask include:

(a) How does the technology transform raw materials into goods and services ?
(b) How efficient is the process in terms of conversion efficiency; through-put per unit of time; energy consumption; other utility consumption; rate of rejects; product quality (however defined);
(c) Cost per unit of output ?

(d) What can go wrong with the technology, and how often can things go wrong ?
(e) What is its impact on the environment ?
(f) To what extent does it meet or exceed regulatory standards or international standards of quality in its output ?
(g) To what extent is it adaptable to changing customer requirements ?
(h) What are the prospects of obsolescence ?
(i) How does it compare with competitive offering ?

This is just a small sample of typical questions one is taught to ask. One is also given enough training to discern right and wrong answers. However, the range also illustrates the type of specialist knowledge that the MOT practitioner has to draw on in order to reach an effective decision. Typically, his/her own specialist knowledge is limited to one or two of the many areas. He/she then draws on other specialists to reach a clear-cut decision. The MOT training lies in asking the right questions and discerning the right answers. It does not consist in generating all the answers, although the manager's original discipline may enable him/her to generate some of the answers. For example, an MOT practitioner from finance background may be able to generate all the cost related answers; the one from engineering may be able to compare specifications and arrive at answers related to process efficiency etc.

Similarly, a question regarding the choice of animal species for multiplication and adoption by farmers goes beyond the technical questions of genetics, weight gain, resistance to pests and diseases, and ease of multiplication. There are sociological questions of farmer and consumer choice of meats; religious taboos; entrenched farming practices etc, which the breeder alone cannot answer.

Table 2: MOT PROGRAMMES BY REGION

(NB: This covers reported long-term (degree or equivalent programmes only and does not include electives and short courses. It is likely to underestimate the total amount of activity, both in terms of numbers of programmes and countries active in MOT)

COUNTRY	Number of reported MOT programmes
Argentina	**1**
Australia	**2**
Austria	**1**
Belgium	**2**
Brazil	**1**
Canada	**10**
Costa Rica	**1**
Colombia	**2**
Denmark	**1**
Finland	**1**
France	**6**
Germany	**1**
Hong Kong	**1**
International schools (INSEAD, IMD, EIT etc.)	**5**
Ireland	**1**
Israel	**2**
Italy	**1**
Japan	**1**
Korea	**2**
Mexico	2
Nigeria	2
P.R.China	2
Puerto Rico	1
South Africa	3
Spain	1
Sweden	2
Switzerland	1
Taiwan	1
Thailand	1
Turkey	3
USA	133
UK	30
Venezuela	1

Sources: Bessant J. (1991); and author's knowledge of Nigeria

IV. Management of Technology in ECA

The World Development Report 1998/1999 elevates the Management of Technology to a new status (probably by default). Having concluded that up to half of the difference between rich and poor nations is due to the difference in acquisition and use of knowledge, the report assigns to international institutions certain critical roles in narrowing between rich and poor nations. These roles are: creating new knowledge, transferring and adapting knowledge the knowledge to the needs of developing countries; and managing knowledge so that it is kept accessible and constantly refreshed. ECA is a critical international institution in this context. The pertinent question is, how equipped is ECA to perform these roles at present ? Put differently, we could ask the question: what must ECA do in order to be able to perform these roles more effectively ?

As defined in the World Development Report, technical knowledge cuts across the divisional boundaries of ECA. It occurs in every division. It must be managed in every division so that the entire institution attains the required capability to perform the three-fold role of bridging the knowledge gaps and solving the information problems of its member states.

At present the science and technology function is limited to the Food Security and Sustainable Development Division (FSSDD) Within that division, there is a team of four people with the following disciplinary background:

Team Leader : Veterinary surgeon/geneticist
Members: 1 Engineer/economists
1 Agronomist/economist

These are the basic components of a multidisciplinary team. How large should the team be ? Given the focus of the division on food security and sustainable development the team could be expanded to include a demographer/ population scientist, and a plant breeder. Each then has the technical competence to contribute to the work of the group. The group then needs basic exposure to the core competencies of MOT that are relevant for food security and sustainable development. This can be achieved through formal courses in established institutions, or through on the job seminars, workshops and training sessions in selected areas of MOT.

A starting point could be:

Managing technical and professional teams:

- team leadership and skills analysis
- definition of project responsibilities
- network analysis

- progress reviews.

Technology impact analysis:
- in-house consequences for employees
- environmental impact assessment
- legal responsibilities
- moral responsibilities
- corporate citizenship.

Technology reviews:
- technology balance sheets
- value chains
- competitor analysis
- profitability calculations

Technology acquisition
- licenses
- market sharing agreements
- consortia
- data protection

Technology policy issues:
- human resource development
- research and development system
- the production system
- the consequences of technological change
- regional development of S&T
- intellectual property management.

Each of these issues could be the subject of a full-blown seminar.

An alternative option is to design a basic course in MOT and expose as many as possible, people from all divisions. Such a core course could include four blocks:

(a) Introduction and background
- definition of MOT
- scope of MOT
- importance of MOT
- component disciplines of MOT

(b) The process of technological change
- definitions of innovation and technological change
- sources of innovation
- process models of innovation

- different disciplinary perspectives.

(c) The economics of technical change:
- sources of competitive advantage
- technology as a source of productivity growth
- price and non-price factors in competition
- evolutionary theories of technological change
- product cycle and technology gap theories
- international comparisons of R&D expenditure and innovative performance
- technological capability accumulation
- diffusion lags.

(c) Innovation at the level of the firm
- innovation success and failure
- a review of international studies
- communication and innovation
- key roles in the innovation process-gatekeepers, product champions etc...
- diffusion models.

A third option is to send members of the S&T team to short MOT courses is reputable institutions such as the Massachusetts Institute of Technology, Harvard Business School, Science Policy Research Unit of the University of Sussex; etc. Each option has its advantages and disadvantages.

CONCLUSION

The management of technology is an emerging discipline that has attracted practitioners from many disciplines. It is little known in Africa, but it is defining the basis of international competitiveness. Africa needs to take it more seriously if it is not to be left behind in the current global effort to come to terms with the phenomenal rate of technological progress.

ANNEXURE 1:

Range of issues from which Management of Technology courses are drawn

(a) The context of technology management

Technology management – an integrative approach

Historical perspective
Technology, economic growth and sustainable development
Systems approaches to the organization of technology
Management
Key technologies – advanced manufacturing, biotechnology, new materials, information technology, etc.
Core technology management issues

Organizations and systems

Images of organizations
Structural and infrastructural dimensions
Organizational analysis
Hard systems' tools
Soft systems' methodologies
Other analytical tools

Control and co-ordination systems

Organization by product, by function, by discipline
Portofolio planning
Project selection
Risks and rewards
Financial appraisal techniques

Management information systems

Rich vs. lean systems
Targets, performance and adaptation
Technical and market requirements
Milestones and schedules
Time vs. cost performance
Company wide vs. local or project control

Organizational effectiveness

Adapting to change
Efficiency and effectiveness in resource usage
New and old yardsticks
New patterns of organization
Organizational development

Technological competence and capability

Core and peripheral technological competencies
In house vs. supplier resources
Joint ventures
Competitor profiling
Integration – vertical and horizontal
Cost management of competence acquisition and development

(b) Strategic management of technology

The importance of, technology strategy

The limitations of past product and market strategies as purely financial strategies

Recent emergence of technology management as a strategic weapon

Integrated technology strategies for products, manufacturing processes and corporate-wide systems.

Review of strategy in national companies

The old colonial focus
Low price, low sophistication strategies for export
High price, high sophistication strategies by foreign import competitors
Short-term profit maximization vs. long-term product, process and market development strategies.

Strategy and global competition

World markets
Market segmentation and price/non price factors
The rise of Japan and the Far East
Competition and local content issues
Emerging markets – Eastern Europe, etc.

Corporate management of technology, developing and manufacturing

- Integration of product, manufacturing, marketing, finance
- Manufacturing strategy and process innovation
- Strategies for flexibility, quality etc.

National and international technology policy

- Technology transfer between civilian and military sectors
- Intervention vs. non-intervention
- Pre-competitive collaborative R and D
- National product champion support
- Small, medium and large firm support policies

Marketing strategies and plans

- Corporate strategy
- Integration of marketing, product and manufacturing strategies
- Product portfolios
- Market segmentation and market shares
- Pricing, sales, volumes and profits
- Distribution and servicing policies

Manpower strategies and plans

- Company and product skills and profiles
- Setting new skills targets
- Integrating manpower skills profiles with finance, marketing, manufacturing and product technology strategies

Education and training strategies

- Sourcing of skills – internal or external
- Make-or-buy decisions
- Policies for de-skilling and/or employee involvement

(c) Technology project management

R and D management

Portfolio planning vs. single make or break projects
New product definition
Progressing research towards development projects
Creativity and new opportunities
Technology selection

Project management

Project control and resource management
Competitor analysis
Project approval
Team building
Competing projects and back-ups
Building project ownership
Project compromises
Project reviews

Financing technology

Rates of return
Technology as investment or cost
Risk and pay-off
Short-term and long term support
Entry and exit costs
Standard vs. "creative" accounting

Advanced manufacturing systems

Integrated systems for products, marketing and manufacturing
Design for manufacturing
Simultaneous engineering
Manufacturing resources planning
Total quality and just in time
Continuous improvement projects

Technological collaboration

Joint ventures
Make/buy policies
Licensing and parent trading
Conglomerates
Subcontracting
Consultancies
Government and NGO facilities and support

Project simulation tools

CAD, CAM
Supplier and user-based systems
Financial simulations
Real time systems
Simulation of large complex projects

Project presentation

New and existing product analysis
Market entry and exit considerations
Success probabilities
Cash flows and break-even analysis
Product profile and factor weightings

(d) Technological change and innovation

Predicting change – technological forecasting

Strategic views and time horizons
Assumptions, inputs and outputs of forecasting
Techniques of forecasting
Evaluation and use of forecasts and forecasting experts

Management of technical change

Product life cycles
Manufacturing capital replacement cycles
System replacement
The S curve – uses and abuses
Log-linear, log – log representations – uses and abuses
Technological substitution

Introduction to creativity

Creativity and organizational inertia
Non-analytical techniques
Analytical techniques
Matrix building
Simulation
Innovative cultures
Managing innovative people

Critical thinking skills

Proper characterization of background issues
Problem statement
Solution precision
Required vs. desirable specifications
Interactions
Cut-off criteria
Analytic and synthetic approaches

Technology selection

Core technological competencies
Accessible external competencies
Mixing internal/external and new/old competencies
Criteria for islands of opportunity
Riskiness and potential for success
Product, process, systems and market positioning
Short-term needs vs. strategic long-term requirements

Technology transfer

Development prototypes to full-scale
Inter company transfers
International transfers
Third party and turnkey projects
Direct and indirect costs
Legal frameworks
Developed/developing country transfers
People based vs. hardware/ software transfers

Entrepreneurs and intrepreneurs

New ventures and intrepreneurs
Entrepreneurs skills and commitment
Organizational support
Corporate venturing
Business planning
Coping with growth

(e) Managing complex products, processes and systems

Understanding success and failure factors

Project management
Degrees of complexity

Reducing complexity
Re-integration of units, interfaces and architectures
Simulation models for development and commissioning

Information systems and technology management

Systems architecture and hierarchy
Control structures
Access and security
Integrity
Protocols and open systems
Speed, power and faithfulness

Advanced manufacturing technologies

CIM
Flexible manufacturing systems
Manufacturing resources planning
Integration issues
Compatibility – internal and external
Flexibility and responsiveness
Upgrade cycles
Networking and open systems

Product innovation

Invention, innovation, re-innovation – resource requirements
Patterns of re-design and re-innovation
Technological paradigms, pathways and trajectories
Robust designs and product families
Product life cycles

Manufacturing innovation

Jobbing, batch, continuous systems of manufacturing
Matching product and process
Lean manufacturing
World class manufacturing

Product/marketing interface

Design for marketability
Make/buy decisions and the value chain
Strategic balancing of product families and life cycles
Managing information

Product market research

- Customer needs
- Needs analysis
- Price/non price factors and balance
- Technology driven and market driven innovation
- Product/market concepts

Designing and developing the supply chain

- Quality issues
- Economics
- Logistics
- Make/buy decisions

(f) Organizing for technology management – professional teams

Managing the corporate culture

- Identification of corporate strategic goals
- Delivering and disseminating information
- Induction, education and training in the culture
- Promotion systems and policies
- Conflict and dispute resolution systems
- People and system excellence

Managing technical professionals and teams

- Team leadership and skills analysis
- Definition of project responsibilities
- Network analysis
- Progress reviews

Managing contractors and suppliers

- Purchasing agents and contractors
- Single vs. multiple sourcing
- Technological integration with suppliers or contractors
- Quality, price and other strategies
- Value chains

Managing collaborative ventures

- Types of collaborative venture

Complementary competencies
Government and non-government schemes
Managing collaborative ventures
Accumulation of expertise

Workforce impacts of technology

Redeployment
Interaction in project planning and/or commissioning
Patterns of organizational change
Deskilling, reskilling and upskilling

Industrial relations

Law of contract and union membership
Management of terms and conditions
Employee representation
EEC regulations and programmes
New technology agreements
Equal opportunities

(g) Technology assessment, law and ethics

Assessment of risk and uncertainty

Technological risks
Technological uncertainty
Historic records and future estimates
Rules of thumb and heuristics
Regulatory requirements

Human error and reliability

Individual and corporate responsibility
Safety training
Operational training
Contingency training
Simulator training
Measuring and monitoring human performance

Technology review – internal and external audits

- Technology balance sheets
- Value chains
- Profit and loss points
- Competitor analysis

Technology impact assessment

- In house consequences for employees
- User and public safety requirements
- Environmental considerations
- Legal responsibilities
- Moral responsibilities
- Corporate citizenship

Technology acquisition

- Licenses
- Market sharing agreements
- Technology sharing agreements
- Consortia
- Confidential agreements
- Data protection

Intellectual property management

- Patents
- Registered designs
- Trademarks
- Copyright
- National and international data systems
- Agents and legal documentation
- Corporate portfolios of intellectual property

Safety and environmental regulation

- Health and safety legislation
- Environmental guidelines and laws
- Government and industry associations
- Structure and operation of regulatory institutions
- Sources of information and advice
- Relations between regulators, industry and interest groups
- Public accountability

Legislative and judicial oversights
Enforcement: institutions, resources and mechanisms
Environmental impact assessments

Technological responsibilities and liabilities

Product, process and system liability
Customer care
After sales service
Supplier development policies
Good citizenship and
Ethical responsibilities
Employee training and development.

Source : Beasant, J. (1991).