ED 346 244 CE 061 206

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TITLE Training for Maintenance in Developing Countries. Training Discussion Paper No. 97.
INSTITUTION International Labcur Office, Geneva (Switzerland).
REPORT NO ISBN-92-2-108424-8
PUB DATE 92
NOTE 37p.
PUB TYPE Reports - Research/Technical (143)

EDRS PRICE MF01 Plus Postage. PC Not Available from EDRS.
DESCRIPTORS *Developing Nations; *Economic Development; *Educational Needs; Educational Policy; Foreign Countries; *Job Training; *Maintenance; Postsecondary Education; Secondary Education; Technical Education; *Vocational Education

ABSTRACT

This paper focuses on training policy issues related to the development of maintenance practices in middle- and low-income developing countries. Chapter 1 provides a definition and discusses various approaches to maintenance. It shows the major trends in maintenance skill changes, such as increased problem-solving and information technology components and growing specialization geared to the type of technology and modes of maintenance applied. Chapter 2 shows the particular mix of technologies used by developing countries and the extent to which the maintenance practices correspond to their needs. It argues that as developing countries install simpler machines, on average they need less sophisticated maintenance. However, since many developing countries have imported modern equipment, they need policies to develop maintenance of corresponding sophistication. The chapter also illustrates how foreign maintenance practices are applied in some developing countries. The last chapter presents the ways vocational training for maintenance is conducted in developing countries. It notes that maintenance skills are usually learned through apprenticeship and that technical education and training in maintenance is still rare. However, transfer of maintenance knowledge has been more active through technical assistance and technology transfer projects. The report suggests some implications for training policies aimed at enhancing maintenance awareness in developing countries. (KC)

TRAINING discussion PAPERS

Training for maintenance in developing countries

by V. Gasskov

Training Policies Branch
International Labour Office Geneva

97

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Training Policies Branch
INTERNATIONAL LABOUR OFFICE GENEVA

ISBN 92-2-108424-8

First published 1992

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Printed by the International Labour Office, Geneva, Switzerland

Introduction

Many developing countries (DCs) are poor and have failed to develop economically. For the past 20 years, in many of them, crisis has steadily deepened. Among the strategies aimed at breaking the vicious cycle of underdevelopment in DCs - increased savings, preferential international trade, foreign aid, etc. - technology transfer is considered as one of the most promising alternatives. Its importance relates to the hope that foreign technologies would be able to bring new production capacities and modern skills and management to generate greater savings and employment. Import substitution has been another serious rationale for the installation of modern machines by those DCs whose foreign exchange budgets are very dependent on imports.[1] However, the viability of the development strategies and benefits from the imported technologies in DCs greatly depend on their ***local capabilities in keeping the machines going. That is the major function of maintenance.*** *In that sense, maintenance capabilities are considered a key development factor for DCs.[2]*

However, poor maintenance has become one of the most intractable problems faced by DCs. Its effects can be seen everywhere - in the factories, fields, housing and public utilities and even in schools. Frequent breakdowns reduce production and crops spoil before they get to the market. Broken equipment, deteriorating facilities, and premature wear lead directly to reduced efficiency, limited options, and low quality.

A study by DeGroote reports some discouraging findings. In over 400 maintenance audits completed in developing countries, technical equipment was only available, on average, 32 per cent of the time.[3] This means that machines in DCs are out of operation for more than two thirds of their theoretical work time, mainly because of maintenance problems. The lack of maintenance has been the major reason why many manufacturing plants constructed in DCs did not reach their potential productive capacity, and also why projects originally designed to generate foreign exchange have had the opposite effect of increasing the exchange deficit.

The need for maintenance does not solely exist in DCs. The importance of maintenance was rediscovered in industrialised countries during the 1960s as capital intensity increased. Since then maintenance has received much attention and new practices have been devised. Managers share the opinion that "maintenance only costs money when it is not done". On the average, in industrialised countries, annual spending on maintenance has amounted to 8 - 12 per cent of the value of machines.[4] Another measure of the maintenance costs is their share in product prices, which is, for example, in the countries of EEC, between 3.5 and 5.0 per cent. This constitutes a huge sum of 70 - 100 bn. Ecus a year.[5] Hence a major problem in these countries is to reduce the costs of maintenance.

To a certain extent, all the reasons stressing the importance of maintenance are also present in DCs. However, maintenance problems are aggravated there by quite a few factors such as the lack of economic incentives, an immature infrastructure, a low level of technical and management education and cultures which are unfavourable to maintenance with their general disregard for its importance. Even greater problems may occur within public enterprises, where there are fewer rewards for good work. Worse, the most severe problems are found in some of the world's poorest nations.

It is instructive to realise, that there are significant regional and country differences. In many DCs of Asia and the Indian subcontinent, good maintenance practice appears to be more highly appreciated and better organized than in other regions of the developing world.[6] Korea, Singapore and Taiwan, for example, have been successful in the application of imported technologies to local conditions. They are competitive in world markets largely because of the effective use of export-oriented technologies which *require very demanding maintenance practice. While in Kenya maintenance is well-developed, it is sub-standard in Burundi, Madagaskar and Zaire.*[7]

In recent years, the UN and its specialized agencies, particularly UNIDO and the ILO, have formulated policy recommendations designed to address maintenance practices in DCs. The UN has recognised that financial aid spent on preventing the deterioration of physical equipment and facilities would be much more cost-effective than the aid granted for initial investments.[8] *As the above-mentioned figures for the EEC indicated, annual maintenance costs do not normally exceed one-tenth of the total value of machines. Maintenance improvements are therefore the least costly way to sustain or increase production efficiency compared to purchasing new machinery, which in its turn, will again require maintenance.*

However, despite considerable efforts and investments made by donors and DCs themselves, many of them still have a poor maintenance culture and practice. Moreover, though the introduction of sound maintenance practice in some DCs initially showed promise, it was subject to rapid erosion later on after the completion of the projects. It seems that though maintenance is often emphasised in technology transfer projects, it is seldom considered as a component of national training policies.

This paper is mainly focused on training policy issues related to the development of maintenance practices in middle and low-income DCs.

Chapter I discusses a definition of and various approaches to maintenance. It shows the major trends in maintenance skill changes - increased problem-solving and information technology components, and growing specialisation geared to the type of technology and modes of maintenance applied. Technical and vocational education and training programmes and maintenance qualifications in industrialised countries are found to gradually follow the development of maintenance practices.

Chapter II shows the particular mix of technologies applied by DCs and the extent to which the maintenance practices applied correspond to their needs. It argues that as DCs install simpler machines, on average they need less sophisticated maintenance. However, as many DCs have imported a good deal of modern equipment, for its cost-effective use, they have to introduce maintenance of appropriate sophistication. For that to happen, they need to develop policies helping to introduce and sustain maintenance practices. This Chapter illustrates how foreign maintenance practices are applied in some DCs. Economic and cultural environments in some DCs are shown to have remarkably little capacity for sustaining proper maintenance practices. However, it was found that even in relatively distorted economies, company policy or even personal ambitions can be a good ground for nurturing proper maintenance practice.

The last Chapter presents the ways vocational training for maintenance is conducted in DCs. Maintenance skills normally learned through apprenticeship have been useful mainly for repairs. Technical education and training in maintenance is still very rare, preventing engineers and technicians in DCs from applying cost-effective maintenance schemes. However, transfer of maintenance knowledge has been more active through technical assistance and commercial technology transfer projects as well as productivity courses. Major groups requiring training in maintenance are discussed as well as the need to establish maintenance qualifications in DCs.

The report suggests some implications for training policies aimed at enhancing maintenance awareness in DCs.

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I. What is maintenance?

Work has traditionally been divided into operational tasks, which embody the actual production process, and maintenance tasks, which are designed to improve capital productivity by reducing machine downtime and increasing the life of equipment. Differences between the operational and maintenance workers could be found not only in their skills, but even in ways of thinking and attitudes. During production time, maintenance workers conduct routine tasks or keep records. As distinct from operational staff, maintenance staff work hard when a machine is down and production is at a standstill.[1]

In the modern work environment, maintenance is redefined as a highly specialised activity aimed at reaching a balance between economic considerations (losses caused by machine downtime, costs of spare parts and of maintenance staff) and technical ones (production time-table, speed and load of a machine, the life-span and degree of wear of the machine parts). For instance, increased machine output can be reached at the expense of deferred maintenance. However, this often results in premature wear and increased costs of replacement of parts and in higher losses from machine downtime. The term "productive maintenance" is often used to highlight the importance of this function to the manufacturing process.

There are various reasons for which capital productivity rises, thereby raising the importance of maintenance. Firstly, machines are very costly, and are becoming even more so. Secondly, many companies, in order to keep their competitiveness in the fast changing markets, now emphasise small batch manufacturing, which requires continuous retuning of equipment.[2] Since retuning usually entails an increase in idle time and an additional reduction of output, production schedules have to be closely linked to maintenance schedules. Maintenance functions, meanwhile, are surpassing operational tasks in terms of sophistication, with computer assistance playing a key role at many levels.

A. Dimensions of the maintenance task

Several general maintenance concepts at different levels of sophistication have been developed.

The simplest concept is *corrective maintenance*, also known as "emergency" or "unplanned" maintenance, which is carried out when a failure occurs. Machine downtime can be minimised if repair procedures are planned in advance and the required tools and parts kept in reserve.

The goal of *preventive maintenance* is a decrease of the likelihood of equipment failure.[3] The underlying principle here is that "prevention is cheaper than cure". Problems are identified and corrected before breakdowns occur. The programme which follows a set schedule, includes the inspection and replacement of parts according to projections of reasonable operating lifespans. Individual manufacturers often provide information about the life expectancy of the equipment.

Predictive maintenance examines the conditions in which machines operate, often applying sophisticated techniques of noise, vibration, and gas analysis, according to established schedules. The accuracy of predictive maintenance is a considerable asset. It allows parts to be repaired or replaced not according to the average life-spans, but immediately before their breakdowns, thus significantly reducing their consumption.[4] This approach is popular in the United Kingdom, where approximately half the companies have implemented some form of condition monitoring and analysis.[5]

Many problems, of course, can be avoided if the machinery and production process are well-designed to begin with. This consideration ended up with a new approach known as *design out maintenance*, which is aimed at improving the maintainability of installations through the better design of equipment, maintenance programmes, and operations. This is an ongoing process, based on a continual accumulation of knowledge about the workplace and corresponding modification in machines and methods.

Making a choice between these approaches for real-life conditions requires high level maintenance skills and knowledge of management. The most important considerations are the cost of the losses of one hour machine downtime (in terms of would-be produced output), the cost of spare parts and maintenance services and the level of maintenance skills available. Some examples of the different decisions will be given in Chapter II.

Making an option of the maintenance concept requires a serious appraisal of the skill level of the staff. For example, if corrective maintenance is applied, then simple maintenance tasks can be carried out by a machine operator without the use of specialised tools or parts. Here the distinction between operative and maintenance functions is murky. Skilled workers or technicians can undertake diagnosis of breakdowns and minor technical repairs and conduct standard part replacements. By contrast, in the case of preventive maintenance, the need for higher qualified personnel such as technicians and the time of their physical presence near the machines is much larger. They carry out lubrication according to lubrication maps and routine machine checks, readjust measuring devices and keep records on the life-time of components in actual working conditions. The most critical repair and preventive tasks may require a team of engineers.

In general, the role of more specialised technicians has expanded dramatically. Because machines are becoming increasingly self-paced, many basic maintenance tasks are disappearing or diminishing in importance. But the remaining tasks tend to be highly complex. Instead of relying on their own personnel, some firms find it necessary to hire a maintenance subcontractor to perform specialised work.[6] This is very much the case in the United Kingdom, where more than 70 per cent of firms hire outside specialists for some of their maintenance needs.[7] For instance, most computer maintenance is carried out by service organisations, with little involvement on the part of the client. Repairs are typically made in workshops, not on the client's premises.[8]

Maintenance, then, has become a complex and multifaceted process. Many companies now appoint maintenance managers, who are responsible for establishing a viable programme of maintenance. Their work includes the development of technical documentation capacity (data sheets, breakdown checklists, etc.), the mobilisation of a forecasting and programming staff, and the acquisition of tools and equipment. Spare parts management, for example, requires developing a stock of critical parts, based on computer records of previous breakdowns. The establishment of a bank of critical parts helps to reduce repair delays and optimises output.

B. Qualifications and skills required

The maintenance staff of a modern firm typically includes managers and supervisors, engineers and technicians, planners, skilled and semi-skilled workers.

What kinds of skills must an employee possess in order to become a productive member of this group? Maintenance work depends on the ability to solve problems. The core element of maintenance skills, therefore, is knowledge of the equipment and its modes of failure.

Problem solving is a knowledge-based function that embraces much risk and uncertainty. It resists routinisation. The more complicated the machine, the more problems may arise. For example, in the paper industry of Australia, the United Kingdom and the United States the proportion of maintenance workers has reached 20 per cent of the total workforce in the plants surveyed because of the increased variety and complexity of machines. This has been accompanied by an increase in skill requirements.[9] Nevertheless, some maintenance functions could be simplified and routines could be assigned to less skilled staff.[10] In addition, machines can perform some of these tasks. For example, the advent of self-diagnostic devices and the use of modular component replacements in telecommunications are eliminating the need for the traditional skills of fitters and electricians.

Despite the fact that maintenance work is getting increasingly specialised raising the need for specialist maintenance qualifications and skills, training programmes for workers often focus exclusively on traditional contents, without demonstrating how a particular skill can be applied to maintenance tasks. In Germany, for instance, the curriculum for the occupation of industrial mechanic still largely neglects general maintenance concepts.[11] This approach is at odds with the increasingly pragmatic and specialised nature of the modern workplace.

Maintenance practice now requires changes in craft training programmes. Many workers find themselves struggling to apply information technology without ever having been in front of a computer keyboard. Side by side with the new maintenance philosophy, there is a great deal of new bewildering terminology found in the modern maintenance environment. That is why training lasts long and, for example in the U.S., on average from six to 12 months are needed to effectively use the installed maintenance systems.[12]

These factors are at work at all levels of the maintenance profession. Firstly, maintenance has become specific knowledge to be taught. The maintenance manager, engineer and technician have to be aware of the above-said maintenance concepts in order to be able to make the right choice and take all the advantages of it The possession of a respected engineering or technical degree does not automatically enable someone to make the right maintenance decisions under real-world conditions. Secondly, the knowledge and skill content of maintenance are industry and technology specific. A maintenance engineer from a paper mill can not readily maintain a sugar factory. The maintenance of computers and robots is quite different from that of pumps and boilers. For these reasons, managerial and technical training programmes now tend to reflect specialisation. State-of-the-art training programmes do not teach "maintenance" concepts. Corrosive maintenance, fleet maintenance, gas and oil transportation maintenance, nitrogen fertiliser maintenance, or petrochemical maintenance are current specialisations.[13] It means that maintenance concepts should be taught over and above solid technical education.

Thirdly, the more complicated the maintenance is applied, the more specialised the skills learned have to be. The emergence of preventive and, especially, predictive maintenance has imposed new requirements on the training of engineers and technicians. As the ability to diagnose a machine and monitor its working conditions in their entirety assumes greater importance, new subjects (e.g. vibration, gas analysis, and non-destructive testing) must be added to the curriculum. The heightened role of financial considerations in influencing maintenance decisions necessitates a familiarity with enterprise economics.

Industrial countries are witnessing the gradual emergence of a consensus on how to meet the challenges of modern maintenance. It is widely agreed, for instance, that universities should establish maintenance curricula for engineers and managers. Similarly, the creation of a nationally-recognised qualification of "maintenance mechanic," to be linked with appropriate training, is considered of primary importance in countries where this does not already exist.[14] The development of condition-monitoring maintenance systems has focused attention on the training of control and instrument technicians.[15]

Because in-house maintenance crews must be familiar with several fields in order to conduct diagnoses of an entire machine, it is now generally recognised that technician training cannot be limited to basic mechanical and electrical skills. It must also include hydraulics, pneumatics, electronics and other relevant subjects.

Many new trends in maintenance education are occurring in industry. Training in the maintenance of new machines is now increasingly provided by their suppliers.[16] Because modern technology is always in a state of flux, specialists require continuous learning and upgrading of their skills. For example, a practicing electronics engineer may need as many as 300 hours per year of extra training in order to keep abreast of developments.

Some companies, seeking to encourage their craftsmen to expand their horizons, have introduced distinctions between different areas of skill. In the iron and steel industry of the U.K., for instance, three main categories have evolved. "Workshop craftsmen" are highly skilled in a traditional skill area, such as that of electrician or fitter. "Plant craftsmen" are responsible for diagnoses and repairs in different sections of the plant. "Process control craftsmen," meanwhile, must possess a broad electromechanical background and a good understanding of plant processes and problem solving.[17]

These developments in the industrialised economies are impressive. So much so, in fact, that some DCs appear to be falling behind more than ever both in operation and maintenance of their imported machines. The gap is widening. The DCs which are concerned about sustained production and services should be attentive in observing the latest developments in maintenance. New demands for maintenance skills and qualifications cannot be avoided particularly for imported sophisticated technologies. Otherwise, their scarce capital will be wasted and debts increased.

II. What is wrong with maintenance in developing countries?

A. Different technologies require different maintenance

1. Selecting technologies

The economies of many DCs combine a small number of public or semi-public enterprises with a large number of small firms and artisan units. The latter employ between 40 per cent - 80 per cent of the total working population of these nations. However, the major infrastructure and service industries, including transport, communications, power, water and construction, are of fundamental importance. In LDCs, where manufacturing remains mostly undeveloped, infrastructure and public services constitute the greater part of all industry.[1] The ability of small business and artisan sectors to introduce any kind of planned maintenance is almost negligible, though they can benefit from applying the essentials of maintenance philosophy and practice. Yet, large public companies, despite greater capabilities, frequently ignore or underestimate the importance of maintenance questions, thus dooming themselves to suffer from many technical and financial problems.

DCs acquire new technologies from three sources: purchase, donor gifts and, in some cases, domestic production. It is reasonable for any country or firm to limit itself to technologies which it is capable of supporting. Many DCs, in fact, realise this. But the question is not without complexities. In some cases - for instance, the airline or coal mining industries - only the most advanced technologies are appropriate or available. As a result, DCs at differing economic levels operate similar installations, though with varying efficiency. While the maintenance of ordinary projects in DCs can - and should - be reasonably simple, the more advanced technologies cannot dispense with sophisticated maintenance systems and skilled staff.

In some cases, there is a strong link between maintenance and safety. Production and service technologies often have the potential to endanger people and environments. Obvious examples include chemical products manufacturing, aircraft transportation, shipbuilding, and coal mining. At the same time, breakdown of the public service industry, e.g. water supply, may also end with disastrous consequences. For example, because of a cable fire in Kafue Gorge in Zambia the hydroelectric power station was immobilised for almost a year. It had happened because the high tension cables had passed their secure life-time age. But the Zambian government did not allocate foreign exchange for the purchase of the new ones, despite the station's importance to the national economy.[2]

Maintenance of machines in public infrastructure and potentially dangerous technologies is of absolutely critical importance, and should only be entrusted to specially trained specialists. Unfortunately, in many DCs safety is not always taken seriously. In many cases, the sole ambition is to get projects into production, leaving maintenance systems and proper training unattended. In the sixties and seventies, for example, LDCs invested heavily in turn-key factories. Such contracts facilitated the rapid acquisition of production units. However, they were not accompanied by the acquisition of technical know-how and knowledge, or the mastering of maintenance skills.[3]

All too often, the economies which supply DCs with new technologies also have an inadequate appreciation of systematic maintenance. Turnkey projects implemented by industrialised countries, for instance, usually neglect to emphasise the maintenance training component. Suppliers, facing intense competition, attempted to secure contracts by slashing the price of their offers. This meant, naturally, a concomitant reduction in services. Maintenance was the first to go, mainly because of its lack of short-term impact. At the time of construction and start-up, nobody was worried about deterioration.

Lack of awareness at the policy making level leads to failure to address maintenance issues during contractual negotiations and the process of purchasing equipment. The consequences emerge later, affecting such areas as technical documentation, spare parts, training of personnel, and standardisation of equipment and parts. After several months of the new machines functioning in DCs, breakdowns occur and it is stated that maintenance has been forgotten. Technical documentation is missing: operator and maintenance manuals, inspection sheets, trouble shooting instructions and spare part lists. While costly spare parts are sometimes in stock, small parts may be missing. Qualified personnel is also missing: task and job descriptions are not established, while the number and qualifications of necessary maintenance personnel are unknown. Maintenance policy and organisation is also non-existent.

As one expert puts it, between 40 and 60 per cent of the firms in DCs have no structured maintenance services. Technicians are scattered around, executing repairs and some lubricating work. Between 20 and 30 per cent have a separate maintenance service, which is considered as a necessary evil. It usually has poor financial and human resources. Only between ten and 20 per cent of firms have organised maintenance installed from the very beginning with external help.[4]

DCs therefore should explore the vital link between the equipment they buy and their ability to maintain it. Before this can happen, though, solid maintenance awareness at the policy making level must be established. Such awareness will, hopefully, enable DCs to recognise inappropriate technologies and to outline ways of adapting foreign maintenance systems to local conditions.

2. The need for skills in standardisation

One crucial problem affecting DCs is the bewildering mix of equipment, tools and spare parts found at many sites. Old machines tend to be exploited long past their expected life-span; as these machines age, it becomes difficult to obtain spare parts. Meanwhile, well-meaning donors often present LDCs with machines and parts which are incompatible with the established operations. The problem is exacerbated by a lack of technical documentation. Many DCs simply cannot afford to properly document a plant, since the cost of such an undertaking may constitute more than ten per cent of the total investment. Moreover, the documents for foreign parts are typically written in the language of the country that produced them, and good translations may not be available. Large firms were found to have much better maintained equipment lists than the others. Small companies with less than 200 employees have rarely organised maintenance services and no systematic equipment inventories.[5]

DCs can best confront these problems by developing awareness of necessary standardisation for imported machines and domestic manufacturing. This entails, among other things, the training of experts in standardisation.[6]

3. The challenge of natural conditions

The climate and environmental conditions of many DCs are strikingly different from those of industrialised countries. This factor introduces added problems which do not exist in the countries from which most equipment is delivered. In India, for example, the computerised controls of CNC machines in the maintenance workshops are obliged to function at temperatures well in excess of the safe limit. Hot, wet conditions cause very rapid corrosion in all equipment made of mild steel. For this reason, in some parts of India, passenger coaches and freight vehicles become completely unserviceable after a short time. Distance, isolation, communication problems and the resultant delays exacerbate the effects of natural conditions.[7]

The sugar industry in Sudan is a typical example of the challenges posed by hot and dusty climates and of serious efforts to cope with them.[8] The rise of plant automation in the industry has led to a greater role for maintenance. Indeed, the proportion of maintenance staff has now reached ten per cent of the total number of employees. Sugar manufacturing is seasonal. Its maintenance, therefore, consists of two major stages: on-crop maintenance and off-crop overhaul maintenance. Nearly 80 per cent of enterprises have introduced versions of a planned maintenance system. Routine preventive maintenance is conducted daily, weekly and monthly. Overhauls are carried out at the end of the season, in accordance with the equipment manufacturer's manual. However, lead times for ordering spare parts range from 13 to 18 months.

Maintenance of agricultural machines in hot and dusty conditions is very demanding. For example, in these conditions, the daily service for a John Deere model 4250 tractor includes checking the engine and transmission oil levels, monitoring the battery electrolite level and the amount of radiator coolant, cleaning the air filter and oil cooler condenser, and draining water and sediment from a fuel tank. Engine oil must be changed every other week (100 hours); engine oil filters must be replaced every six weeks (300 hours).

In Sudan, skilled engineers and technicians are very scarce. This is unfortunate, since many are required for proper maintenance of advanced sugar machinery. To a great extent, the training of maintenance staff is conducted on the job. Maintenance engineers and supervisors receive training in the Sennar Sugar Training Centre, which has established a continuous maintenance training programme. Some of the engineers and supervisors are sent to Egypt, Germany and India for advanced training.

This case illustrates that in the conditions of DCs's remoteness from spare parts manufacturers, planned maintenance acquires even greater importance. Some machine manufacturers have adjusted maintenance recommendations to the DCs climate. Companies in DCs which have managed to develop sound maintenance organisations and took maintenance guides seriously have been better off as regards crops and manufacturing compared to many others, examples of which are given below.

B. Distorted incentives penalise maintenance

Maintenance is an element of the economy and, as such, it is inevitably linked to productivity concepts. One of the major causes of poor maintenance in some DCs has been the so-called "crisis of governance", in which bureaucracies provide no incentives for developing productivity.[9] In addition, some governments have negative attitudes towards maintenance. Administrators in these countries prefer to be associated with the glamour of new construction rather than with the more mundane responsibilities of properly maintaining existing facilities. Systematic maintenance cannot take hold in distorted economies where inefficiency is pervasive and incentives for good (and disincentives for poor) work do not exist. For example in Morocco, enterprises were found to be maintenance-conscious, while economic policies of high centralisation and control employed by the government preclude them from benefitting from maintenance expenditures.[10]

The link with economics suggest that market development and privatisation, with their built-in incentives, are vital to the establishment of proper maintenance. In general, the record of maintenance in public enterprises has been unimpressive. Such enterprises are rarely powered by market forces. Instead, they depend on simple discipline and the pressures of central planning. Maintenance performed by profit-driven enterprises, by contrast, seems to be much more reliable and long-term.

1. Cement Industry in Uganda

Many enterprises in DCs fall short of their rated productivity levels, and a lack of proper maintenance is often the culprit. In African countries, for example, an estimated 30 per cent of production capacity losses is due to maintenance problems. In some especially severe cases, enterprises require complete rehabilitation because of poor maintenance. The cement industry in Uganda is an example.[11] Two major cement plants in that country have a combined installed capacity of 450,000 tons per annum. Yet actual production output remains at between four and six per cent of that figure, mainly because of a lack of planned maintenance. Neither the operational staff (especially mill operators, burners, electricians and quality control personnel) nor maintenance workers have received vocational training. The results are conspicuous. Kilns run under uncontrolled temperatures. Cranes, pumps and compressors are damaged. Operations frequently come to a halt because of insufficient energy and water and the non-availability of raw materials. Spare parts are unavailable because of a lack of foreign exchange. About half the workers are idle at any given time.

2. Food Industries in Burkina Faso and Cameroon

Poor management and organisation in some DCs have always been serious reasons behind insufficient maintenance. For example, a Cameroon brewery went bankrupt as no maintenance organisation was established. The plant was left 100 per cent overcrowded by low-skilled workers. The new equipment was quickly left in poor shape. One boiler exploded as all security devices were eliminated. In the corn mills of Burkina Faso, maintenance workers only know day by day what repairs to execute. There is no planned maintenance. Very often maintenance workers have no specific tasks as they are practically integrated in the production teams. All this means that the need for maintenance specialist skills and qualifications is not well-understood.[12]

3. Maintenance development project in Ethiopia

The difficulties faced by countries lacking a developed market economy are well illustrated by Ethiopia's attempts to introduce a long-term maintenance development project. During the project's initiation stage about 950 managers, supervisors and ministry officials together with 7000 maintenance mechanics and drivers undertook various forms of training in maintenance. More than 85 enterprises conducted maintenance development projects with the help of external advisors. These efforts ended up with large increases in the availability of equipment and a reduction in maintenance costs.[13] But subsequent evidence has shown that many enterprises which had introduced maintenance under pressure from the authorities soon lost interest.[14] Without economic incentives, there was little reason for them to bother. Though the Ethiopian Management Institute trains about 100 managers in maintenance every year , most of them have still not established appropriate maintenance.[15]

Proper maintenance in Ethiopia was found to survive in two industries: sugar and petroleum refining.[16] In both cases, maintenance was established a long time ago, and has continued through the years in the form of daily, weekly and monthly routines. Periodic inspections are carried out. The guidelines established by the manufacturers' manuals are followed. Sound maintenance plans are developed, and the staff is thoroughly trained.

Success in these industries originated with the entrepeneurs who founded them. They were well-educated in their fields and had clear goals in mind. They accepted good standards of preventive maintenance from abroad, and trained capable workers to keep accurate records and conduct annual overhauls. In addition, maintenance workers were well-paid; their comparatively high salaries and generous bonuses encouraged them to remain at their jobs. After the departure of the entrepreneurs, these sound practices were carried on by the workers.

The Ethiopian food manufacturing industry tells a very different story. Management has been characterised by a lack of technical knowledge and a preoccupation with short term investments. From the beginning, maintenance was regarded not as a beneficial invest ment, but as a source of high costs - hence, something to be avoided. Few inspections took place. Tools and parts were not acquired, manuals were ignored, and maintenance workers were burdened with the lowest wages in the entire industry. The absence of skilled engineers ensured that an awareness of the benefits of maintenance would never develop. Repairs were made only when equipment had broken down and a crisis had erupted.

This example says that sound economic incentives for sustaining productivity improvement are the best environment for nurturing sound maintenance practices. However, even in the discouraging conditions of planned economies, the role of educated and ambitious managers and engineers to create sustaining maintenance cultures has been significant. That means that it is a good idea to educate as many people as possible in maintenance. The effort will pay in the long run.

C. Cultural limitations to maintenance awareness

The world of maintenance embraces a variety of ideas, skills and know-how. Some are rather simple, others quite complicated. For many technologies, learning maintenance tasks takes more time than putting them into practice.[17] In any case, their implementation in DCs requires a certain level of literacy and general skills of the staff.

Unfortunately, it is a fact of life in some DCs that education and training are rarely appreciated. Many production workers in charge of modern machines are illiterate or semiliterate. Obviously, they have trouble reading maintenance guides and processing maintenance information. Their understanding of the diagnosis and inspection of machinery is based on an unsatisfactory framework of low technical skills. Their background in general economics is .rely sufficient for the implementation of maintenance economics.[18] In addition, they have not been taught to work effectively. How can such employees be expected to perform demanding maintenance work?[19]

Most DCs do not have much in the way of industrial traditions and experience. The population has typically grown up in a rural, non-technical environment, with little exposure to machines, instruments and mechanical processes. Their formal schooling - assuming they have had any - has filled few of the gaps. Thus, many individuals have no innate sense of what is "normal" and what is "wrong" in the production units. They may simply assume, for instance, that the noise of machinery is normal. Such employees frequently disregard safety precautions and pay little attention to the maintenance requirements of tools, machinery and equipment.[20]

In many DCs technical education does not receive priority, representing a small fraction in education and training programmes. For example, in Cameroon, only one young person in four is being trained for a technical career.[21]

Experts have noted that maintenance ideas are better appreciated in certain DCs than elsewhere. Asia, generally speaking, is a maintenance skill surplus area; Burma, India, Pakistan and Sri Lanka have demonstrated special aptitude. By contrast, Africa is a maintenance deficit area, though not uniformly so. As one source puts it, "those who know Nairobi and Lagos airports will be at a loss to understand why one is as good as new while the other appears to be suffering from neglect".[22]

A number of factors are at play here, especially cultural values which seem to be strongly related to the nature of the maintenance concept and practice. For instance, many LDCs represent the kind of society in which achievement at work is not much valued.[23] Therefore work-related personal success and wealth are to be discouraged. According to this world view, achievement and hard work are never rewarded; power and authority are the guarantors of survival.[24] Therefore, there is little reason to care about improving work habits or productivity. Work incentives, whatever the type, have little effect. The only concept which holds any value is "status" or "authority." Not surprisingly, maintenance and repair work are held in very low esteem. Machine operators, in fact, would consider it an insult to be held accountable for the cleaning of their machines.[25]

Another type of society is characterised by a neglect of procedures, standards and plans.[26] Accounting, measuring, and the collection and processing of information are given peremptory treatment, and performed without accuracy or care. A research study conducted by UNRISD in 1973 has identified specific types of industrial behaviour in countries where this world view prevails. To begin with, the employees frequently have a poor sense of time. There is also a lack of working accuracy and precision, and a resistance to following instructions. Tasks which require quick adjustments, correct measurements, and detailed procedures pose considerable difficulties. The employees often fail to comprehend the necessity of sequential maintenance procedures (doing first things first), and are inclined towards improvisation. They tend to become bored with the systematic repetition of tasks involved in daily maintenance or periodic inspections.[27]

In a real sense, then, there is a "clash of cultures". The cultural values of the country are at odds with the values required to establish, operate and sustain maintenance systems. Maintenance concepts are alien, there is little in the way of precedent to guide behaviour, role models are lacking, and incentives are weak. In such cases, developing a successful maintenance system requires considerably more than providing instruction in appropriate practices. Cultural values have to be addressed on a broad front. Specific maintenance practices have to be embeded in organisational practices which contribute to creating a "maintenance culture".

However, it is worth emphasising that though cultural values are important for the development of the maintenance culture, the rewarding power of economic stimulus should not be underestimated. The experts reviewing maintenance practices in 12 African countries argue that the "maintenance state of mind" is only rarely spontaneous.[28]

D. Lack of skills and ambition for maintenance

Maintenance standards in some DCs are considerably different from those of industrialised countries. What passes for a "maintenance programme" in Ghana or Nigeria would be more accurately described as simple repair: the workers make no attempt to inspect machines for signs of future breakdowns, and remain idle until an emergency occurs. Multinationals, however, like Cadbury (Nigeria), Guinness (Nigeria), or Nestle (Ghana) appear to work under different maintenance concepts more as we have defined them so these concepts might then trickle into local enterprises.[29] Some national firms were also found to keep up maintenance practice. For example, the Zairian copper mines, the Indian Steel industry S.A.I.L., the Tunisian cable factory and electric component plant have well-established maintenance organisations with computerised spare part filing. A gold mine in Burkina Faso and a textile industry in Indonesia were also found to have well-maintained equipment.[30]

Some DCs - for example India - have decided to introduce preventive maintenance on a broad scale, and have organised training courses with this in mind (largely at the technician and maintenance engineer levels). Many African DCs, on the other hand, have focused on breakdown maintenance, offering training primarily to operatives and low level technicians capable of undertaking standard part replacement and minor preventive maintenance, including machine checks and lubrication. Some specialised courses are also conducted for engineers and technicians dealing with renovation or reconstruction.[31]

At this point, we may find it useful to examine in detail some specific cases in which DCs have attempted to introduce maintenance systems. The first example, Sri Lanka, demonstrates the importance of technology and skill considerations. By contrast, the experience of Nigeria has been largely conditioned by attitudes towards technical education. Iran, Mexico and the Sultanate of Oman - all high-income DCs - provide examples that illustrate what happens when national income and maintenance practices fail to match. In contrast, the case of a Zambian mine hospital provides evidence that sound maintenance could be established by the individual public companies even in discouraging environments.

1. Maintenance of construction equipment in Sri Lanka

Breakdown maintenance, preventive maintenance and a combination of the two were the major approaches targeted by the authorities responsible for implementing changes. Locally produced water pumps, as low value equipment, were put under a "breakdown system" based on the replacement of failed units. For tractors, as a higher cost technology, preventive maintenance was chosen. For cutter section dredgers - a very high cost technology required to work 24 hours a day and 6.5 days a week - a combination of breakdown and preventive maintenance was adopted.

In purchasing cutter section dredgers, preference was given to the diesel-electric type, rather than the diesel-hydraulic type, because of the local staff's limited hydraulics skills. The supplier's agent provided training while the equipment was being assembled. It was also agreed that the supplier would provide maintenance during the first year of operation, to compensate for the local staff's lack of skills.

As a rule, manufacturer's maintenance recommendations do not work well in many DCs, mostly because of their poor capabilities. During the introduction of preventive maintenance in the suction dredger project, the manufacturer's recommendations were used only as guidelines. This policy had some unfortunate consequences. For instance, fuel often became dirty because of careless transfer to the tank, necessitating more frequent inspections and replacing of filters. The transmission and hydraulic oil tanks, located on either side of the operator's seat, were often filled with the incorrect grade of oil. To compensate for the low quality of the available lubricant, the cutter shaft's underwater bearings had to be greased every two hours. But in fact, the maintenance crew did so only twice a day. The result: abnormal wear of the cutter shaft.[32]

This case shows, that even in low-income DCs a good understanding and proper selection of maintenance concepts could be achieved. However, the usefulness of maintenance routines should be well understood at the supervisory and craftsman levels. Besides skills, right attitudes towards maintenance should pervade the local staff.

2. The low status of technical education in Nigeria

In most Nigerian enterprises, breakdown maintenance has continued to prevail, and efforts to introduce preventive maintenance have stalled. The low social status of technical education is largely to blame, since it has resulted in an insufficient level of maintenance knowledge among policymakers and entrepreneurs. The higher education institutions provide graduates with a general engineering profile, on the assumption that they will acquire maintenance skills in industry. But that never happens. Meanwhile, experienced maintenance technicians who were trained in-service are not rewarded with proper wages and high esteem.

The problem is compounded by a lack of policies for technology transfer. Since most equipment is imported, there are the usual problems with applying the manufacturer's instructions. Maintenance engineers and technicians are rarely involved in the selection and purchase of equipment and ordering of spare parts. A national body charged with raising maintenance standards, establishing qualifications and drawing up syllabi might help alleviate matters, but none exists. No public training resources are specifically allocated to maintenance.[33]

3. Petrochemical industries of high-income developing countries

Iran, Mexico and the Sultanate of Oman are all countries with highly capital-intensive and technologically complex petrochemical industries. A variety of specialised skills are required to operate and maintain the range of primary and auxilliary equipment installed at all levels, from the multi-million dollar oil refinery to the simple pump station. Maintenance is complicated by the fact that most oil fields in some of these countries are found in remote areas characterised by temperature extremes, dusty and humid atmospheres, and salty air - all of which are detrimental to the well-being of equipment.

These countries can afford to invest heavily in sophisticated machinery. Unfortunately, their spending power does not always match their levels of maintenance practices. Some companies use breakdown maintenance, which may be the most appropriate system for unattended remote installations, where equipment is run non-stop until it breaks down. Moreover, preventive maintenance in these countries is often labour-intensive and expensive. Spare parts are especially costly, and the standards of preventive maintenance often require replacing them before their useful service life has been exhausted.

Theoretically, preventive maintenance is capable of minimising downtime, reducing the cost of spare parts, and eliminating the unnecessary disruption of equipment. These benefits, however, cannot be achieved without a high level of skills and commitment. In some companies, neither are widely available. For instance, poor maintenance skills can lead to accelerated equipment deterioration after seals and bearings have been disturbed. As a result, the equipment may actually end up in worse condition than was the case prior to overhaul.

The countries in question have different standards of maintenance. For instance, maintenance practices in the Sultanate of Oman are relatively well-established and sophisticated. Mexico also enjoys comparatively good maintenance. In Iran, by contrast, it is judged to be of generally poor quality. The reasons behind these disparities are complex. All three countries depend largely on oil exports to finance development. However, they are at different stages of industrial and human resources development. Their priorities vary, along with the amount of proven reserves and the supply of skilled or trainable workers.

For example, Oman has only recently established an oil industry. Its reserves, in fact, are still quite modest. Lacking both skilled and unskilled workers, Oman has had to depend on the expertise of Royal Dutch Shell. From a maintenance viewpoint, this has proven beneficial. The multinational helped organise good training for maintenance staff, and implemented preventive maintenance procedures which have provided a high degree of equipment availability and reliability. Maintenance procedures were a form of technology transfer.

The situation in Iran is strikingly different. Its oil industry has flourished for over 40 years, and reserves are plentiful. However, poor maintenance practices have led to a significant loss of machinery and production volume. Although appropriate models of maintenance could readily be found in industrialised countries, the National Iranian Oil Company has chosen to rely on its own (inadequate) methods of planning and project management. As a result, activities remain more or less uncoordinated, to the continuing detriment of production and equipment. A supporting maintenance culture has not been developed.

Mexico is more industrialised than either Iran or Oman. Its petrochemical industry, while less mature than Iran's, is more solidly established than Oman's. The high level of maintenance is clearly linked with the high percentage of Petroleos Mexicanos managers and engineers trained in the U.S., where they encounter some very sophisticated petrochemical technologies. Of the petrochemical industries in the countries examined, only Mexico appears capable of employing the most complex predictive maintenance systems with good results.[34] Of course, this greater familiarity with advanced maintenance practices is just as much the result of Mexico's widespread industrialisation which is not at all comparable with that of the other two countries mentioned.

4. Sound maintenance in Zambian mine hospitals

The public sector in Zambia is facing great difficulties in providing sustainable medical equipment services. In public hospitals, about 20 per cent of medical equipment is working at fault and 40 per cent is completely out of operation. There are no medical instrumentation training courses available for public sector personnel, and training for plant maintenance is limited to one refrigeration and air-conditioning certificate course.

The Zambia Consolidated Copper Mines (ZCCM) have established a health care system of their own, separate from the public sector and consisting of 11 hospitals and 58 health centres. Despite the poor national maintenance practice, ZCCM have developed a good maintenance system for medical equipment (which happens to be of the same age as that in the public sector). Their ability to achieve this has been due to the following factors:

- Being a private company, ZCCM have established working practices which encourage good performance from their staff, combined with strong supervision and incentives. They offer better conditions of service for staff than the public sector, and staff retention is higher. They provide salaries which are 25 per cent higher and various fringe benefits.

- They recognise the importance of maintenance in both operation and health care activities. Due to the higher efficiency of the private mine sector, the mine hospitals are significantly better financed than their public sector counterparts and therefore receive adequate maintenance budgets and foreign exchange.

- ZCCM have separated and centralised medical equipment maintenance and safety policies, spare part procurement and maintenance and user training from the mine operational divisions. Technical and human resources, maintenance and management expertise from industrial instrumentation have wisely been applied to medical applications.

- Initial training in management and maintenance for the health care specialists was conducted by the mine operational staff. At present, some operational maintenance staff are seconded to the mine hospitals. Special maintenance teams for medical equipment are being developed. Since 1971 one of the ZCCM training schools has introduced biomedical training and 3-5 day modular maintenance training courses on medical equipment for the experienced instrumentation technicians. A 36 week course for maintenance technicians has recently been developed and is due to start shortly.[35]

This case gives another example of how sound maintenance could be established by the individual companies, which transfer appreciation of maintenance from production sites to even health and care equipment. Good maintenance is catching due to the sound management and well-established training system.

5. Applicability of various maintenance systems in DCs's skill contexts

The "operating to failure" policy is probably the only viable system in those DCs, where local engineering and craft skills, management and resources are inadequate to follow preventive maintenance schemes.

Preventive maintenance could be a realistic model for DCs with considerable manufacturing experience but suffering from a shortage of equipment diagnostic skills, though having technicians and craftspeople capable of following maintenance programmes. Maintenance schedules could be established on the basis of machine manufacturer recommendations. The application of preventive maintenance could be limited by the general and technical literacy levels, because technicians need to be able to read and understand maintenance manuals. Besides, records need to be kept on machine operation. Otherwise there is a danger of "overmaintenance", which DCs can not afford.

Maintenance cost statistics would be more important in some DCs, than in industrialised economies, providing reasoning for obtaining foreign exchange from public funds for spare parts.[36] Many firms with poor maintenance understanding but with access to scarce public funds or donors's budgets, buy spare parts "for safety's sake" which is of no use and just costs money.[37] Another consideration, which may require additional skills from local technical staff is that equipment manufacturers recommendations do not always fit the conditions in DCs well. Given the shortage of their engineering skills, they would need assistance from foreign experts to modify preventive maintenance programmes.

In contrast to the others, *predictive maintenance* is applicable only when good engineering skills in electronics, hydraulics, mechanics and pneumatics are developed and motivation for planning, collecting and processing data is there. Engineers and technicians should also be trained in methods of machine diagnostics and condition-monitoring. Application of this costly maintenance approach makes sense only for very expensive equipment, like oil-refinery and paper machines, provided that a number of necessary conditions have been developed.

Design-out maintenance can considerably reduce the need for maintenance activities in DCs. Some DCs have begun to actively participate in the preparation of specifications for machines to be designed or re-designed for their use. In some machines designed for ports, new provisions preventing rust have been introduced on the basis of proposals from DCs.[38] Design-out maintenance means a long history of well-established links between the machine manufacturers and users and, clearly, solid local research and engineering resources are required for this.

E. Why are some DCs better at maintenance than others?

Some middle and low-income DCs are besieged with a number of hard to solve problems like hunger, lack of water, diseases, unemployment. In general, maintenance ideas have not been emphasised in these countries, because they represent a long-term perspective and do not give an immediate solution to some of these most urgent problems. Besides, sound maintenance requires an entire package to be put together - special tools and spare parts, specialist training and incentives, which some DCs are often unable to provide. Instead, the major benefit of maintenance - reduced downtime - may bring new problems to solve, such as the need for more raw materials to feed machines or improved productivity may be accompanied by greater redundancy.

Every country has its own set of specific conditions. Nevertheless, we can isolate and summarise some of the general trends and factors which are likely to influence the quality of maintenance systems:

- The form of economic ownership plays a crucial role. Private property, as a rule, begets a higher concern for maintenance.

Market-driven proprietors are likely to take care of their capital investments. In contrast, managers of public enterprises are less inclined to do so. Maintenance and productivity are related. Therefore, economic and administrative incentives for improving productivity can also be expected to have a beneficial effect on maintenance.

- The level of economic efficiency of an enterprise determines whether it will have the foreign exchange capabilities necessary to plan and carry out maintenance without external financing. In planned economies, where hard currency for purchasing spare parts is provided by ministries, any flexible maintenance programme can be stalled by central planning rules, according to which spares need to be ordered several years in advance.

- Even the most carefully designed programme may easily fail if not supported by appropriate cultural values. Belief in achievement and respect for accuracy and long-term planning are the foundations on which good maintenance can be built. Maintenance awareness, together with the requisite skills, can be transmitted through vocational education and training. In the workplace, prestige and a decent salary are key elements of a positive maintenance environment.

- The national system of education and training in some DCs has enabled them to develop sound maintenance standards. Respect for higher technical education, the introduction of maintenance qualifications and maintenance skill development programmes together with maintenance management courses have been very influential for that.

- The elements of human personality, though very hard to quantify, can be vital to the success or failure of any enterprise. The right people in the right places may prove capable of establishing relatively good maintenance even when the socioeconomic or cultural forces are against them.

Mature maintenance involves a well-balanced combination of management, economics, and industrial engineering. No single factor is enough to ensure the success of a maintenance enterprise. Even strong market or administrative pressures may be of limited effect if the cultural values are unfavourable or the wrong people are in positions of authority. On the other hand, one or two solid prerequisites may form a basis for establishing the others. A plant manager, operating within a framework of sound incentives for productivity and maintenance, may undertake the gradual development of a new organisational culture suitable for maintenance. In some cases, beneficial cultural attitudes may be undercut by a lack of educational input, resulting in the degeneration of sophisticated capabilities into more primitive skills, such as cleaning or greasing. In some high-income DCs, neglect of maintenance know-how is the one factor hindering the introduction of sophisticated systems of predictive maintenance.

As we have already emphasised, maintenance constitutes an entire system of knowledge. A certain logic governs the introduction of maintenance systems into any country, the first stage of which should be building of awareness. Though it may not be identical to the logic that applies in industrial countries, it is equally vital and cannot be bypassed. A long lead-in period should be anticipated, during which standards of accuracy and cleanliness are established. Every single enterprise must decide what level of maintenance sophistication it can support, given its specific conditions. Many enterprises, having failed to take this into account, are currently unable to achieve much beyond simple repairs.

Maintenance should be taught to policy makers, proprietors, managers, engineers, technicians and craftsmen alike. Like any other factor, awareness is not a panacea. With enough commitment, it may allow the fulfillment of the other prerequisites.

III. Can training improve maintenance in developing countries?

A. New concepts for maintenance training

Because they depend so heavily on foreign technologies, DCs should anticipate a need to provide maintenance training for three major groups. The *first* of these embraces policy makers, national planning and training specialists and local investors.[1] Training programmes should focus on maintenance policies development, national spare parts planning and standardisation, technology transfer arrangements, and the respective costs and budgets.

The *second* group consists of maintenance engineers and managers capable of carrying out feasibility studies, choice of technology and maintenance schemes. For example, the properly trained engineer or manager will recognise that expensive centrally lubricated bearings are only justified in situations where there is no possibility of developing the skilled staff necessary for the use of manually serviced bearings. Training should encompass methods of standardisation and evaluation of spare parts needs, and should create familiarity with the technical documentation involved in running and maintaining imported plants. Finally, managers and engineers should learn to develop specifications and establish conditions required for the local manufacture of spare parts.[2] In many DCs, for example in Zaire, general maintenance engineers are often more in short supply than other specialists.[3]

Managers and engineers must be trained to analyse various approaches to maintenance and identify those which are most appropriate to the conditions in their particular industry and country. Should on-site maintenance be favoured over external contracts? Should preventive and breakdown maintenance be combined? These are the kinds of questions effective training should prepare them to answer.

Technicians and craftsmen make up the *third* group. They require less knowledge of maintenance theory but specialised training in the methods of machine control (vibration and lubrication monitoring, crack detection) and machine tooling (fitting and grinding), electrical repair, welding and oxycutting, and in computer applications. They also need to be taught spare part and technical documentation management, in areas of storage, coding, stock control and technical documents use and updating.[4] The most difficult level in training is that of foremen. They largely acquire their skills through a long period of practical experience. Leadership training is also necessary for those technicians and craftsmen assigned to supervisory positions.[5]

This means that there are certain differences between the qualifications of a "general engineer" and a "maintenance engineer" as well as between the qualifications of a "technician" and "maintenance technician". The more sophisticated technologies and maintenance systems are in use, the more training and upgrading maintenance specialists might need.

The issue of interest to us is what kind of training policy would be the best suited to develop maintenance specialists in less industrialised DCs.

1. Institution-based education and training

The main problem with institution-based education and training in some DCs is that it often fails to prepare potential engineers, technicians and managers for the world of maintenance. Analyses conducted at several ports in DCs indicate that maintenance managers are usually equipped with general technical education. They are, by and large, graduates of university engineering programmes. Junior managers may have a polytechnic degree, or some other equivalent qualification. But most have not received specialised training in maintenance or management.[6] Insufficient knowledge of the economics of the enterprise is often the major reason for considering investment in maintenance as a mere cost with no fruitful impact on productivity. Therefore, a solid approach to maintenance cannot be expected.

The pace of dissemination of proper maintenance practice in DCs significantly depends on maintenance education. Firstly, the introduction of maintenance subjects into the curricula of higher education institutions, technical colleges and vocational schools is an absolute necessity. For instance, several African nations (Cameroon, Gabon, Mali and Senegal) have decided to establish higher education diplomas in maintenance.[7] Secondly, the general engineering skills as well as maintenance skills of graduates need further adjustment to the technological conditions of particular firms. As few firms in DCs can offer such in-plant courses, except in particularly sophisticated industries, specific technology-related skills need to be further developed in specialised training institutions, which could be organised, for example, by employers' groups. Unfortunately, maintenance qualifications do not receive national attention in most DCs.[8]

In medium and high-income DCs, maintenance ideas are promoted through a multitude of maintenance management and up-grading courses offered mainly by productivity centres. Since maintenance management programmes often do not focus on particular technologies, they can be offered to various industries. For example, in Turkey, training in maintenance for engineers and technicians is provided by the Small and Medium Size Industries Training Centre (SMITC), Middle East Technical University and quite a few other public and private institutions. SMITC conducts about 2000 maintenance training programmes in the areas of management, pneumatics, hydraulics, CAD/CAM, flexible machining systems, and electronics.[9]

In Brazil, some modular courses have been developed for corrective and preventive maintenance. New training programmes have been introduced for automated technologies processing chemicals and petrochemicals, for transport (with the participation of "Mercedes"), for CNC and CAD machine-tools and robotics systems, for microprocessors and peripheral equipment. Training in electronics has been extended in the existing curricula.[10]

2. The importance of general technical training

Let us begin with a hypothetical example. A vendor arrives and conducts a training programme on the operation or repair of a certain type of pump. The maintenance staff learn very little, and the vendor is blamed for a poor programme. The real culprit, however, may be the students' lack of basic knowledge: what a pump is, how to operate it, and what safety procedures to follow. The vendor assumed a certain level of knowledge which the schools, in fact, have not provided.

Many technicians in middle and low-income DCs lack general technical knowledge and skills to perform routine mechanical servicing and repair, let alone the more complex tasks of maintaining hydraulic and electronic components. These countries are frequently burdened with a scarcity of skilled workers in such areas as electronics, automation, pneumatics, hydraulics, and inventory management. DCs urgently need maintenance technician and craftsman training programmes for apprentices and adult trainees who do not possess basic technical skills. These programmes should cover indispensable subjects, such as technical drawing and other symbolic displays. A clear understanding of maintenance manuals is necessary. These are often written in a foreign language. Therefore, all technical training curricula should include some form of language study.

For example in Sri Lanka, there are no formal maintenance qualifications either for engineers or for technicians. Technicians and craftspeople are trained mainly on the basis of apprenticeship programmes without particular emphasis on maintenance ideas. There is no tradition for craftspeople being multiskilled. Formal training for technicians, craftspeople and foremen is provided by the institutes, developed with external assistance from Germany, Japan, Sweden and the World Bank, some of which are trying to introduce Diplomas in maintenance.[11]

To avoid this kind of situation, technical and vocational schools in some African countries have decided to expand courses for technicians at the general craft level. Cote d'Ivoire and Mauritius have included maintenance subjects in their technician education programmes.[12] Algeria and India are in the process of establishing maintenance training institutes. Guinea, Niger and Mali are creating workshop-schools.[13] Burundi decided to introduce sections of maintenance in vocational schools and to establish an institute responsible for preparation of training programmes on maintenance.[14] In Tanzania, maintenance and repair courses are being introduced in vocational schools.[15] As school-based training in many other DCs cannot be relied on to produce properly trained workers, solid in-plant courses and apprenticeship schemes may offer the only realistic solution.[16]

UNIDO has developed interregional programmes in this field based on the activities of national centres of excellence.[17] Normally, training for a maintenance technician lasts 4-6 weeks. In some industries, like aircraft or petrochemicals, training could be much longer - up to 12 or even 48 weeks. Usually all the courses demand that the trainees should have up to three years of industrial experience. But this is because many trainees from DCs do not possess necessary levels of technical education. In any case advanced courses need to include general technical subjects in their programmes.

At present, most maintenance training courses are very often a means of correcting shortcomings of technical and vocational education. To the extent that maintenance subjects will become a part of school-based training, most training courses should switch to upgrading and retraining in maintenance.

3. Employer training

Large enterprises and multinationals in some DCs provide a lot of training in maintenance in their own training centres, though it is often too narrow, leaving out many important components, such as maintenance organisation and spare part management.[18] As for small and medium enterprises, they normally cannot afford to employ maintenance specialists and are therefore obliged to contract out maintenance services to larger enterprises or specialist firms. For example, one of the UNIDO projects in Vietnam is dealing with training of a mobile unit for provision of maintenance services for the small business sector. Most medium and small enterprises cannot afford expenditures on external training. For them some form of apprenticeship would be the only viable option. However, in some countries maintenance practice in the informal sector was sometimes found to be better than in public enterprises. In addition greater awareness of maintenance due to private ownership prevails in informal firms. Another reason for this was found to be the higher cost of credit for the informal sector's investment in equipment, compared to that for the formal one.[19]

4. Results-oriented training: the case of Ethiopia

This particular trainer training method was developed and successfully practiced in Ethiopia[20] and Tanzania[21]. The essence of results-oriented training consists in managers and supervisors being taught maintenance subjects to become "transmitters" of maintenance skills for their 10-15 subordinates. This method has the following advantages compared to the others:

- The supervisors are involved and not bypassed by the training scheme as is often the case. Instead of resenting or being undermined by new subordinates' skills they become more knowledgeable and have to know their subordinates' work in detail. For example in Ethiopia, foremen participated in two-week courses - one week for upgrading in general technical skills and one week for training in maintenance.

- The training period is much shorter. This is because an external consultant deals directly with experienced people who later become the trainers themselves. This initiated a wide multiplication effect. In due course, the training done by the transmitter is shorter because only topics directly relevant to the situation are dealt with.

For example, several hundred Ethiopian managers and supervisors and 6000 mechanics and drivers were trained in maintenance in four months. Amongst the maintenance staff in Ethiopia only 30 per cent underwent training in courses, while 40 per cent learned maintenance from peers ("transmitters"), 20 per cent from reading manufacturers's manuals and the rest learned from other sources. In addition, training courses in Ethiopia had been designed on the basis of diagnoses of maintenance problems. This, too had helped to significantly reduce training programmes. For example, for the training of the "Toyota" vehicle mechanics this permitted dealing with only 23 critical maintenance items instead of 62. The training modules, prepared by the ILO, were used, however, after some adaptation.

Despite the fact that tailor-made training is very narrow and presumes low flexibility of maintenance workers across enterprises and sectors, it is capable of solving some immediate maintenance problems of DCs, although many conditions have to be favourable for its successful implementation.

5. Training for spare part manufacturing and reconditioning

The ability to renovate complete machines, assemblies and individual components could dramatically improve conditions for many enterprises in DCs. The life-span of components is limited, especially in agro-industries. When these components are large, heavy and expensive, and the supply source is remote, it is much better to renovate than to replace. However, this requires special training in reconditioning techniques, such as metallisation and welding, the rewinding of large electrical motors, and metal deposition. Local technicians and craftsmen can be familiarised with the high level skills required to perform major mechanical and electrical renovation. The development of reconditioning and manufacturing specialists also has the potential to increase the employment of the local workforce.

6. The need for multiskilled maintenance specialists

Inasmuch as machines are generally becoming more complicated, better diagnostic skills and an understanding of complete systems are increasingly valuable. This, in turn, creates a need for craftsmen to acquire flexibility across a number of trades. A new qualification of multiskilled specialist - the maintenance mechanic - is the most likely beneficiary of the emerging trends. International organisations are now working with some DCs to establish this new qualification in places where it does not already exist. Such work has been carried out in Algeria, Morocco and Nigeria, with the goal of achieving recognition of maintenance as a separate industrial occupation and securing the inclusion of maintenance skills in technical training syllabi. In most national systems of vocational education and training, maintenance is not presently seen as a distinct qualification or subject.[22]

The broadening of maintenance skills may impinge on traditional craft boundaries and may, therefore, affect labour relations and employment policies. As in industrialised countries, in

DCs the inclination to employ more people and preserve job fragmentation is a powerful factor. Training of separate skills is often more likely to win acceptance than creation of a combined trade. In Pakistan, where there is a surplus of craft skills, multi-skilled training has received little appreciation. By contrast, attitudes in Nigeria and Singapore appear to be much more favourable.[23]

B. Upgrading of maintenance skills through technical assistance

For many DCs, maintenance ideas are transmitted through multinationals and foreign aid. However, the first aim of the projects is to produce as soon and quickly as possible. The usual picture is therefore that the foreign constructor starts the new plant or installation, and once the guarantee-production level is reached with the help of highly qualified expatriates, the well-running equipment is left in the hands of poorly instructed and qualified people.[24] Much can be done to speed the acquisition of new maintenance capabilities through technology transfer and reconstruction joint projects with foreign firms.

1. Involving local maintenance staff is not enough

The best way for local staff to start learning maintenance is through participating in the construction and installation of new projects. This involvement can occur both on-site and at the supplier's works. But, firstly, many suppliers were found to have no experience either in operation or in training, particularly in conditions of DCs, which represent a very limited market for them.[25] And, secondly, a full cycle of maintenance work is never conducted during the installation and start-up stages. That is why the future maintenance staff should preferably be trained by the users of equivalent equipment than by manufacturers.[26] While constructing its first large shipyard, for example, South Korea sent fifty workers to a shipyard in Scotland to gain hands-on experience. Similarly, Brazil's decision to send many technical personnel for training at a petrochemical plant in France greatly expedited the start-up process for its own project.[27] Most Japanese firms are willing to arrange training programmes in Japan for technical staff from countries that adopt their technologies. In addition, the Japanese government encourages technical training within DCs, with particular attention given to middle-level technicians.[28]

2. Creation of a national maintenance infrastructure in Nigeria

In Nigeria, some industries with the support of foreign companies and multinationals are encouraging development projects that include maintenance training components.[29] For example, mechanics in towns all over the country are being trained to service Peugeot cars, which are assembled in Nigeria. In big towns, spare part depots and service centres for the maintenance of Caterpillar and Fiat-Allis construction equipment and agricultural machinery have been introduced. The standardisation of equipment and spare parts manufacturing is now underway.

3. Strategies of reconstruction

The differences in maintenance awareness between LDCs are most evident at the level of reconstruction and modernisation. In Africa, for example, an impressive number of production units are being reconstructed. In 1984, for instance, European companies carried out several such projects, including an oil-mill in the Congo, a textile mill in Mozambique, a pineapple cannery in Guinea, an ammonia plant in Algeria, and textile plants in Chad and Cameroon. Unfortunately, the rehabilitation of these units was accompanied by very little, if any, maintenance training for the local staff. Another cycle of misoperation is to be expected.

By contrast, the modernisation of old plants in India has been carried out with the direct involvement of local engineers and technicians. Indian companies, before signing contracts with foreign interests, demand preliminary studies, though they are often very costly. Indian industrialists prefer to remain in charge of the modifications. This approach is a proven way to acquire broad expertise in modernisation and other levels of maintenance.[30]

4. Interpreting foreign maintenance manuals

Local staff in DCs should be trained to be cautious in their view of manuals provided by foreign suppliers. Many of these manuals are not appropriate to local conditions. In addition, technicians unused to reading technical documents may find them hard to comprehend. Some countries insist on approving maintenance and operating manuals before the final acceptance of equipment. Of course, inspection of manuals requires high level skills from local engineers, and must be carried out together with the contractor's specialists.[31]

5. Including training specifications in contracts

Most technology transfer contracts, in addressing training specifications, provide little more than a vague estimate of the number of staff to be trained. Therefore, it is hardly surprising that the training provided by manufacturers is very inadequate. In one DC, a port has invested millions of dollars in new equipment, while appointing only one (part-time) training officer to the project. This example is not at all atypical. As a rule, training specifications should play as important a role in contracts as technical specifications. The previous training and current skills of the relevant personnel should be described in detail, so that suppliers can structure their programmes and teaching methods.[32]

6. Training methods

New methods of maintenance training are to be encouraged. Currently, workers with low literacy and little experience seldom receive satisfactory training in DCs, whether within the framework of industrial projects or in vocational training courses. Strictly cognitive instruction is less successful than instruction which combines all aspects of task performance.[33] In Japanese firms, where language barriers impede communication with firms in LDCs, "learning by doing" has proved more attractive than reliance on printed instructions.[34]

Modular training is an effective approach, because of the suitability of maintenance routines to modularisation. A training module on maintenance is included, among the other 34 units, in the "Modular programme for supervisory development", prepared by the ILO.[35] In addition, with the ILO's guidance, 230 modular units have been developed for use in projects designed to enhance maintenance skills of supervisors and managers in the automotive and heavy equipment industries.[36] At the craft level, a modular training programme for the category of general maintenance mechanic suitable for trainees with a relatively high level of general education, has been developed in the ILO.

Generally speaking, distance learning should also contribute to the rapid expansion of maintenance knowledge in firms where the trainees are highly committed and possess strong self-discipline.[37] In industrialised countries, video tapes and computer-based training (CBT) programmes have been developed and successfully used by some industries in maintenance craft training. At the management level, for instance, a comprehensive maintenance training kit/package has been developed for instructing engineers, either as a distance learning tool or a course of instruction. It is comprised of work books, audio and video cassettes, hands-on manual test and work kits. However, the costs of these materials are still prohibitively high and most companies do not have the resources to support them. Some programmes are available on hire though.[38]

However, middle and low-income DCs seem to be much worse equipped with training programmes appropriate to their conditions. For example, it seems necessary to develop modular training programmes combining both maintenance, supervisory and craft skills for the qualification of maintenance technician to be used specifically in middle and low-income DCs. In addition, machine manufacturers with large involvement in DC markets may find it cost-effective to develop modular or distance learning training programmes, for the maintenance of the equipment they export. Such programmes could be used for in-plant training with the help of instructors. Given the remoteness of DCs from suppliers and their shortage of training funds, such training would be more pervasive and cheaper to carry-out.

IV. Implications for training policies

For many developing countries bringing in imported technologies has become one of the major hopes for their economic and social survival. However, some of them have been unable to take advantage of modern machinery due to their inadequate capacity to maintain it. The more frequently modern equipment is installed in various sectors of developing countries - in industry, agriculture, education and health and public utilities - the more evident are the effects of the shortages of systematic maintenance skills and awareness of the general topic of maintenance. In some developing countries, machines were found to be out of operation more than two thirds of their work time. Frequent equipment breakdowns lower productivity, create shortages of the most urgent services and result in wasting the countries's scarce foreign exchange and increase indebtedness. For this reason, improving maintenance practices seems to be a very cost-efficient investment alternative, compared to new investments. However, it has to be well-organised and sustained by well-trained and committed staff.

Developing countries have shown significant differences in their attitudes towards maintenance. It was found that even well-planned long-term maintenance development strategies cannot help countries with distorted economies which produce no incentives for productivity improvement. Perfect maintenance is of little interest to a firm which cannot benefit from it. Administrative pressure alone is not sufficient to ensure committed maintenance. An economically conducive environment must be established, in which enterprises are penalised for the practices that allow frequent breakdowns and excessive spending on spare parts and, finally, shorten equipment life. Firms and individuals must have incentives to adopt constructive maintenance practices.

Some developing countries suffer from the inadequacies of their national technical and vocational education. Lack of solid general training precludes success in implementing good maintenance programmes. In such countries, maintenance training is generally limited to craftsman training, leaving them short of the sets of skills required for more sophisticated maintenance modes. In these countries, technicians rarely receive training in maintenance skills. Policy makers, investors, engineers, supervisors and managers seldom receive any training that would make them more aware of the benefits of maintenance. Maintenance skills learned through simple apprenticeship schemes are useful mainly for repairs, but not to undertake broad and far reaching maintenance programmes and policies.

In the prevailing command economies and centralised public training sectors of many developing countries, maintenance can better be introduced through the expansion of their technical education and by including general maintenance subjects in the curricula of higher education, technical colleges and vocational training schools. The introduction of qualifications such as maintenance engineer and technician needs to be encouraged. A training policy aimed at fostering maintenance awareness could play an important role in any national strategy. It is a good idea to teach maintenance to as many people as possible. The effort will be worth it in the long run.

However good school-based maintenance might be, a certain period of in-service maintenance training is absolutely necessary. Unfortunately, except in multinationals and large enterprises in developing countries, firm-based training is little developed. Many enterprises mainly rely on public training funds and programmes, where possible. Employers' associations must take the lead in establishing specialised training centres on a cost-shared base and introduce training and up-grading programmes for maintenance staff. In the poor developing countries, efforts need to be made to establish solid apprenticeship schemes for maintenance specialists.

In many developing countries, values and attitudes that are unfavourable to good maintenance prevail. These include disrespect for planning and work procedures, and a lack of achievement motivation. In fact, failure to implement appropriate maintenance practices may not be because of the lack of know-how and information. Failure often results from inappropriate attitudes - a conflict with cultural values and distorted economic policies. The question of cultural values is a delicate one and creating an attitude favourable to maintenance cannot be done overnight. The greatest challenge may be to develop the context in which an appropriate maintenance culture can be nurtured. This requires full commitment on the part of the firm, a sound price and wage system, adequate incentives, strong leadership and solid training and up-grading.

In some developing countries little effort has been made to harness the enthusiasm and ambitions of local specialists, employers and faculty staff in the diffusion of maintenance ideas and values. Bringing together people from various levels who share an interest in maintenance facilitates a healthy interplay of ideas. In turn, this kind of exchange aids the development of maintenance qualifications, specialised skill standards and diplomas and training courses. The establishment of associations of maintenance engineers and managers should be encouraged. Such organisations promote maintenance development and help ensure public recognition.

Some developing countries continue to install modern machines while failing to foster the necessary maintenance capabilities. Machines will not work reliably without proper maintenance, no matter how sophisticated the technology. Before purchasing a new installation, every government, donor or local enterprise must be alerted to the danger of not meeting the maintenance requirements. Will it be possible to deploy a sufficient number of maintenance engineers, technicians and craftworkers, as well as workers capable of producing the necessary spare parts? How quickly can maintenance employees be trained, and how much will they cost? Generally speaking, if an enterprise is not serious about maintaining machines, they should not be purchased. However, the broad spread of maintenance awareness and skills in both public and private sectors of developing countries seems to be the only way of avoiding the wrong import practices.

Maintenance schemes will be unavoidably different in developing countries. Their experience has shown that similar equipment can be serviced in many different ways. Maintenance schemes may range from the very simple to the very complicated. However, in the case of modern technologies the choices are no longer wide. Only firms that manage to develop maintenance schemes of considerable sophistication and motivate well-trained and committed staff can succeed. Whenever developing countries opt or are forced to opt for these complex technologies, they may not have the choice either. These machines might require complex maintenance procedures, even when installed in poor countries. In these cases, the countries have to make the effort to master the maintenance skills or avoid these machines altogether.

In general, good maintenance practices have been found in developing countries with healthy economies and favourable cultures, providing incentives for enterprising managers and engineers. By contrast, maintenance practices are the worst in poor developing countries, which can least afford to waste their resources and capital. The demand for better maintenance is manifest. However, the establishment of sound maintenance in such developing countries is handicapped by the same reasons as are other general economic and social matters like productivity, environment, health, education. Yet, the exceptions presented by the examples of successful firms in these countries give evidence that some enterprises have managed to sustain relatively good maintenance and productivity levels even in non-rewarding environments. The crucial reasons for that have been the presence of some well-educated, trained and ambitious managers and technical staff. Since the implementation of radical economic reforms is beyond our scope, the second-best solution would be an expansion of the movement towards productivity and maintenance awareness in order to focus scarce education and training investments on human resources development. The training investment in creation of maintenance awareness and skills would be able, at least, to generate generous revenues just by helping to improve the countries' and firms' policies regarding their technological imports.

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