The Management of Port Equipment Maintenance

University of Wales College of Cardiff Performance Associates, Inc.

AUGUST 1990

Technical Paper

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The basic structure and contents of this Technical Paper have been put together by Performance Associates, Inc., a firm of consultants, based in California, USA, specializing in operating, maintenance and material management problems for heavy industry, mining, utility and mobile equipment operators on a world-wide basis and have developed sound, proven methods of controlling costs and improving performance. They prepared this paper while consultants to the Transport Division of the Infrastructure and Urban Development Department of the World Bank. Gilmore R. Tostengard, Principal, Stephen R. Brown, Principal, and C. Jay Dunton, Senior Consultant, were joint authors.

The background to the paper is a detailed survey and review of port maintenance practices and management prepared for the World Bank and carried out by the University of Wales College of Cardiff, UK, and financed mainly by the UK Department of Trade and Industry but with some additional assistance from UNCTAD. The Bank is extremely grateful to the UK DTI for their generous assistance and keen interest in this vital topic. The Bank also acknowledges the considerable time and effort so generously provided by the management and staff of the various ports that were associated with the survey.

Throughout the development of the survey, this Technical Paper and the IPP-3 Seminar, the Bank has worked closely with the Ports Section of the Shipping Division of UNCTAD. The Bank is very grateful for the assistance provided by UNCTAD and is also conscious of the valuable cooperative relationship that has developed between the two organisations which will, hopefully, be for the greater benefit of the port industries in developing countries.

The need for both this Technical Paper (and the associated UNCTAD Seminar) was conceived by John R. Lethbridge, Ports Advisor, World Bank, who was responsible for the preparation, production and also wrote the introduction.
# THE MANAGEMENT OF PORT MAINTENANCE

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Is there a Problem with Port Maintenance?

An efficient port system is an essential requirement for a country's trade regime. Developing countries aiming to compete in the export markets of the world cannot help but recognize the importance of well-managed ports. Where essential cargo-handling equipment is not available due to breakdown, spare parts are unavailable, or the port capacity is unable to respond in a timely manner to the demands of ship operators, the cargo passing through the port will inevitably reach its final destination bearing higher costs and longer delays. Whether a port is large or small, it has a large investment in mechanical equipment and infrastructure that obviously needs to be maintained and protected. The management of port equipment maintenance is probably the most serious operational problem facing port managers in developing countries.

To gauge the scale of the problem, the Bank carried out a survey of port maintenance practices in both industrialized and developing countries. The survey confirmed that many less developed countries (LDCs) are experiencing serious port maintenance problems and, worse, that these problems are steadily increasing as their ports struggle to acquire and manage the more complex cargo-handling equipment needed to respond to the ship operators demands. It is important to realize that the problem of port maintenance is one of management -- management that has its origins in the way in which a government manages its ports. This report examines the issues that senior government officials, port authorities and port managers need to address to turn port maintenance into a well-managed, properly funded function. A detailed guide explaining how port management can achieve effective maintenance is presented in a World Bank Technical Paper INU-57 of which this is the executive summary.

Survey of Port Maintenance Practices

A review of port maintenance practices was carried out in 1988 by a team of experts under the auspices of the Department of Maritime Studies, University of Wales Institute of Science and Technology (UWIST). Its purpose was to determine the extent of maintenance problems, their causes, the methods several ports have used to overcome them, and the type of action that is needed where the problems remain unresolved. Therefore, the survey covered some ports in which maintenance is fairly well managed as well as those known to have problems.

Geographically, the survey sample can be divided into two groups: seven European ports (Felixstowe, Grimsby, Immingham, Southampton, Port Talbot, Bremmerhaven, and Antwerp) and nine LDC ports (Alexandria, Dar-es-Salaam, Madras, Bombay, Colombo, Singapore, Penang, Buenaventura, Santa Maria, and Cartagena). Maintenance practices were examined mainly for mechanical
equipment for handling cargo or other operations, but also for floating craft, electrical installations, dredging, infrastructure/civil works, and navigation aids.

The scope of maintenance work performed by ports varied considerably. In some instances, the port or port authority maintains all the facilities, from marine craft to civil works, to cargo-handling equipment. In other cases, the port authority was primarily a "landlord" and the facilities and equipment were operated or maintained by an independent organizations, which may be a public or private entity. Most ports fell somewhere between these two approaches. Irrespective of the form of organization, poor maintenance had the same negative impact on the national economy.

Main Findings of the Survey

Maintenance deficiencies were evident in all port activities. In some categories, particularly mechanical equipment, the problems had reached crisis proportions in a few LDC ports. Although the personnel interviewed cited technical inadequacies, shortcomings in the engineering departments, and the lack of spare parts as the main cause of these problems, the root actually appeared to lie in the institutional, administrative, and managerial aspects of port operations - notably, in inappropriate control and regulation, poorly formulated government and port policies and objectives, constraints imposed by central planning bodies, and inappropriate organizational structures and inadequate planning mechanisms. Surprisingly, the technical competence of the engineering staff was seldom the reason for poor maintenance.

The survey indicated the widespread failure to recognize the very significant costs of maintenance. Equipment maintenance alone accounted for 15 to 25 percent of total port operating expenditures and was frequently a port's largest single expenditure item. Even so, budgets at the government and port levels often failed to provide appropriate funds to cover these costs, in part because of misconceptions about maintenance priorities or the lack of accurate information about costs. Indeed, most management information systems and data on maintenance and equipment performance were found to be inadequate, unreliable, fragmentary and to contain little costs information. Some managers seemed unaware of the fact that it costs more to maintain equipment than to purchase it. As a result, decision making, particularly with respect to maintenance costs, was not based on sound reasoning.

The relationship between port operations and maintenance was often ambiguous and the position of the managers of these two major port activities poorly defined. In many ports, too often the operations manager was dominant and the maintenance manager had little authority over equipment use. As a direct consequence, regular planned maintenance was impossible to carry out and the department's morale was low. In fact, employee motivation left much to be desired at all levels. Many of the staff had negative attitudes toward their jobs, and inefficient maintenance appeared to be invariably linked to poor management of both the maintenance function and human resources.

Many of the poorer country ports had difficulty in gaining access to foreign exchange (even though they may be a major source of foreign exchange
generation), and consequently were unable to purchase, on a regular basis, much-needed spare parts, special materials, or lubricants, and the time-to-time services of the foreign technicians needed for specialist complex tasks. Although the types of problems varied from country to country, several were prevalent throughout the LDCs investigated and should certainly be given high priority in any efforts at reform. The main issues concerned government involvement, organizational weaknesses, inadequate maintenance objectives and policy, funding deficiencies, and inadequate maintenance practices and programs:

- **Government Involvement**

Although some governments in both industrialized and developing countries are considering or introducing institutional reforms to separate port management from ownership and are allowing the private sector to manage some port activities, in most of the LDC ports surveyed port organizations had strong links with government ministries. More often than not, these links made it difficult for ports to manage their maintenance and operational functions. Governments often interfered in day-to-day port activities, even to the point of approving individual purchase orders for spare or replacement parts. To make matters worse, some interministerial approvals might take as long as four months - a delay that simply increased the maintenance task and worsened the port's ability to provide services. In several countries, this interference was actually on the increase. In contrast, European ports tend to operate with a high degree of autonomy, as do most ports in North America.

One aspect of port activities in which the LDC government was usually involved was long-range planning, most notably, five-year plans of port traffic, revenue, operating costs, and new investments. Many central planning units exercised direct control over the implementation of the plans. This approach wrested authority from port management, which in many of the ports surveyed was not even allowed to review and revise its own tariff and port charges. Many LDC ports were also subjected to inflexible government controls over expenditures and procurement policies, which left the ports unable to respond to changes in traffic demand because they could not obtain the cargo-handling equipment they required, or could not import the spare parts needed to carry out essential equipment repairs.

In addition, some governments imposed employment restrictions on ports to keep them in line with general government policy. As a result, competent and energetic personnel were discouraged from seeking employment at ports, or left for positions in the private sector as soon as they had the necessary skills and experience. In some cases, governments had the power to veto specific activities of port employees or to place employees of their own choice into the port organization. However, it has been shown that extensive government control of day-to-day operational activities not only leads to inappropriate decisions, increased costs and substantial delays, but also stifles initiative and enthusiasm throughout the port organization.

If the government's objectives are to provide assistance with overall port policy, strategies and objectives, then the government should make certain that appropriate departments are assigned to participate in this
activity. In a number of LDC ports, the ministries that were directly involved in port activities often had little understanding of port affairs and thus tended to give higher priority to issues that they were more familiar with. This direct government involvement is frequently partly responsible for many of the problems that traditionally burden port maintenance. However, many governments today, faced with macro-economic issues, are seeking means to increase the efficiency of their para-statal organizations, including ports, and are experimenting with increased autonomy and increased use of the private sector. Thus the scene may be improving for the better.

- Organizational Weaknesses

The most frequently observed organizational problem was the lack of clear lines of responsibility. Frequently, the responsibility for port performance was divided between different departments in the organization, or the managers assigned a responsibility did not, in fact, have the authority to carry it out. The major port issue was the lack of coordination between the maintenance and operations departments who were often found to be working at cross purposes. In a typical scenario, the maintenance department would request equipment for programmed preventive or other maintenance, but the operations department could not release it because it was needed for essential cargo handling. Consequently, the equipment remained in service well beyond the preventive maintenance schedule, until it eventually failed, whereupon the equipment was finally turned over to the maintenance department for repair. But, since the maintenance staff was not prepared for the breakdown, it was slow in returning the equipment to operations. This reinforced the operations department's reluctance to "give" the equipment to maintenance because they "never get it back." The conflict between these departments was in many cases the direct result of little or no joint planning, scheduling, or coordination of known tasks - a management issue.

Another common organizational problem in LDC ports was that maintenance management was too far removed from the technicians to keep in touch with the realities of the workshops or to monitor performance. Many ports had an engineering department head of equal standing to the operations manager, but this person usually had a civil engineering background and the electrical, mechanical equipment and other maintenance managers reported to him. Because new civil works investments appeared more prestigious and got greater recognition from senior management, the maintenance function tended to be regarded as a nuisance and was consequently neglected. Where managers were remote and indifferent, motivation (and thus productivity) was poor. Indeed, it was found that many employees had negative attitudes toward their work even though their jobs may have been protected by social legislation or collective labor agreements. In many cases, poor salaries, levels of pay and benefits accounted for the lack of pride in the workplace, but overstaffing coupled with lack of skills was also found to have a negative impact on performance and productivity. Relatively few ports seemed to be adequately making an effort to forecast staffing needs or to plan recruiting activities. Moreover, their recruiting functions were often hampered by bureaucratic, cultural, and governmental constraints.
Employee performance in many LDC ports was also constrained by the lack of access to appropriate training programs. In the past few decades, port equipment has become increasingly sophisticated and complex, but the maintenance and operations personnel have generally not kept abreast of technological changes. In some cases, skills in electronics, diesel-electric, automation, and instrumentation were even below safe levels, as one European port discovered when it hired a group of 12 replacement equipment operators who were inadequately trained. That year the port experienced a threefold increase in accidents, while maintenance costs jumped $450,000. Many ports have also indicated that they have had to prematurely scrap equipment because their poorly trained maintenance staff and equipment operators had effectively destroyed it.

Inadequate training has been particularly serious in cases where new plant and equipment have been installed. Substandard maintenance often followed commissioning and the problem did not seem to be alleviated when the equipment vendor was used as a source of training. In these cases, workers have to cope with language differences, instructors are not skilled in the art of instruction, insufficient time is allotted for the training, or the training fails to take into account the learning needs of the trainees. Often, the wrong people are selected for the training. By and large, however, the cause of poor maintenance performance in the study samples was the lack of management skills.

**Inadequate Maintenance Objectives and Policy**

One of the more disturbing findings was that many LDC governments and ports had failed to set clearly defined financial or performance goals. Where an effort had been made to establish such objectives, they tended to be vague or unrealistic. One port, for example, expected to return 24 percent of surplus funds to the government as a deemed dividend on top of a 50 percent tax on the surplus while servicing three sizable foreign currency loans. As a result, it was left without enough funds to carry out proper maintenance of equipment and timely replacement. Such objectives merely promoted the general decline of port equipment and ensured a continuing reduction in financial returns.

As already mentioned, the maintenance work force was poorly motivated in most LDC ports. This problem was due not only to organizational deficiencies, but also to the lack of clearly defined performance and staff goals - such as "absenteeism should not exceed 3.5 percent." Management showed little inclination to systematically identify the goals that could help improve employee productivity or to adopt the approaches and practices needed to improve maintenance. Instead, the survey found large deficiencies in the management of both the fixed and mobile equipment in the LDC ports surveyed. In the absence of clear maintenance objectives, the complement of cargo-handling equipment seldom matched the workload imposed by the actual cargo traffic and equipment was frequently kept in service well beyond its economic life.

The lack of a systematic equipment replacement policy also caused enormous problems for maintenance. Under normal circumstances, it can take
many months and often more than one year to procure new cargo-handling equipment, but the time was stretched out even further in most of the ports surveyed because of excessive government controls and interference. Furthermore, management failed to keep adequate records of present demand, utilization and operating costs of equipment on which to base predictions of future equipment requirements, and there was a general reluctance to dispose of exhausted or obsolete assets. Where management had prepared an equipment plan, it usually failed to determine appropriate equipment inventories. Although most ports prepare traffic forecasts for five to ten years into the future, the predictions were often unreliable and insufficiently detailed for equipment planning needs, particularly in the unitized and conventional general cargo trades. The equipment planning process was poorly managed even when ports had received quantities of equipment through aid projects. In those cases, the attitude toward equipment planning tended to be relaxed because it was assumed that more aid equipment would be forthcoming, and the net result was uneconomic use of equipment.

Although it may seem obvious that the decision to replace existing equipment with newly purchased equipment should be made in the same way as any other investment decision - that is, on the basis of the discounted cash flow rate of return on the investment - the procurement practices and policies observed in LDC ports were seldom guided by this principle. In many cases, ports were required to purchase equipment through local dealers rather than directly from the manufacturer, often at significantly higher cost to the port and with diminished service since the local agent could not supply adequate technical support. In more extreme cases, some ports were required to purchase from local manufacturers, if available, and were restricted from considering any other sources.

In many LDC countries there was a tendency to apply the same regulations to the purchase of spare parts as were applied to the purchase of equipment. The problem here is that the purchase of capital equipment requires considerable care and analysis because many options are usually available and the decision will have long-lasting implications covering the life of the equipment. The purchase of spare parts, on the other hand, offers relatively few options and is vital to the cargo-handling capability of the port. Spare parts purchases are repetitive, occurring virtually every day, and therefore must be streamlined and under the direct control of port management.

Still another procurement problem was that aid programs tended to give ports little choice in the selection of equipment. In one case observed, a port had eight different makes of forklift trucks of the same capacity, but with no common components. In another instance, temperate climate equipment was being supplied to a port operating in a tropical climate. The major issue is that equipment specifications and procurement documents were seldom adequately prepared, and that few ports followed or had any inkling of effective procedures for writing specifications and preparing bidding documents - especially concerning the future supply and flows of spare parts. In fact, most port personnel were unqualified to prepare the specifications, since this often required specialized technical knowledge. Although some ports prepared general specifications, identifying characteristics such as dimensions, weight, rail gauge, engine rpm's, and so on, they tended to
overlook the importance of functional specifications related to the needs of the port, such as lifting capacity, cycle speeds, lifting height, and minimum time allowed for preventive maintenance service.

In the absence of a systematic approach to procurement, many fleets consisted of a variety of makes and models of equipment. Consequently, their operating, maintenance, and financial problems tended to be more serious than in fleets with more standardized equipment. Few operators were trained and qualified to handle all the different types of equipment, productivity tended to be lower in these ports, more accidents occurred, and there was more equipment damage. To avoid some of these problems, as well as the long delays often experienced in obtaining spare parts, many LDC ports attempted to purchase repair parts at the same time they ordered new equipment. It was common practice, for example to include a two-year supply of parts in equipment purchase orders - based sometimes on the manufacturer’s recommendation - most manufacturers have little operating experience of their own equipment especially in aggressive climates. However, this approach tied up more money and warehouse space than was required, and many of the parts that were purchased in this way were never needed or decayed because of storage climatic conditions. As a result, the scarce funds that were available were all too often spent inappropriately.

An important finding concerns the manuals supplied with equipment which were frequently found to be poorly organized, filled with information about models other than the ones they were using, printed poorly, difficult to understand by people unaccustomed to reading technical documents, and lacking in clearly understood explanatory diagrams. Few were translated into the national working languages.

The survey also found that port management seldom employed a sound procurement policy and bid evaluation procedures. Instead, subjective and superficial ranking criteria were used to identify equipment and little effort was made to carry out a detailed review of equipment performance capabilities to ensure that they met the specific needs of the port, to check the supplier performance and support record, and to consider life cycle costing. Generally, port management failed to appreciate the need for outside skilled technical support in both the preparation of specifications and the technical evaluation of the bids and the enormous value to be gained from their use.

- **Funding Deficiencies**

One of the most serious problems facing the maintenance departments in LDC ports is a shortage of foreign exchange for the purchase of spare parts and equipment replacement. All ports earn foreign exchange, but most of the LDC ports surveyed were not allowed to retain as much as 3% of their revenues, even though they make large operating surpluses. Generally, the ports did not accumulate reserves for equipment replacement. The few that did keep some reserves in local currency had to compete with other segments of the economy for the scarce foreign exchange resources.

Spare parts required a significant expenditure each year. The maintenance costs for typical cargo-handling equipment ranged from 4% to 18%
of the equipment replacement cost. Spare parts represented 20% to 45% of the total maintenance costs. Most, if not all, of the cost of spare parts will require foreign exchange. Ports were seldom given autonomous control over the foreign exchange and local currency revenue they generated, although a few LDC governments had allowed their ports to earmark portions of their foreign exchange earnings for the purchase of spare parts, materials and foreign experts but not for equipment replacement. One port, for instance, was allowed to retain a proportion of its foreign exchange earnings in a London, UK, account and had direct custody over the revolving fund account from which it drew funds, when required. The revolving account was based on budgeted estimates of foreign exchange needs and was subject to year end audit.

Many of the port organizations studied complained about the difficulty adjusting budgets to changing circumstances. Often actual conditions were significantly different from those that were anticipated when the budget was prepared. One prevalent problem was a significant deviation in the volume and type of cargo from what had been expected, yet LDC ports failed to recognize the benefit of having a flexible budget. Instead, budgetary controls are tight and ports are often required to purchase the lowest-priced equipment without regard to operational and maintenance performance, fleet standardization, or service capability.

- Maintenance Practices and Programs

The survey found deficiencies in all the maintenance activities commonly performed: preventive, corrective, component rebuild and parts fabrication, and failure analysis. LDC ports tended to perform most of the preventive maintenance (PM) and corrective work in-house, and relied on outside contractors for only the most specialized tasks, even though the in-house staff and equipment might not be able to perform the work reliably or cost effectively. In all these categories, maintenance was greatly influenced by the manner in which the equipment was operated. In many LDC ports, poorly educated and ill-trained equipment operators often do not understand the mechanical principles of the equipment and are thus unaware of the damages or excessive wear that resulted from their actions. Lack of maintenance of the paved surfaces in the port's working areas also results in damage, excessive wear and accidents. Overall, the ports lacked well-conceived and clearly understood operating procedures backed up by careful recruitment, selection and training. Indeed, one of the conclusions of the survey was that improved operating procedures and improved operator training are urgently needed in the LDC ports.

One maintenance practice that was common in LDC ports concerns "cannibalization," which refers to the use of parts from one "down" unit of equipment to repair another. This approach has become widespread in LDC countries because of the extensive delays in the procurement of vital spare parts and materials. Usually, the cannibalization is self-defeating because it continues indefinitely, and the equipment unit is never restored. Among the many factors that contributed to the dearth of parts was the lack of foreign exchange, the neglect of forward planning of parts requirements, governmental restrictions and approvals, port internal delays in issuing purchase orders, errors in maintaining inventory records, inappropriate stock
replenishment logic and inventory management procedures, misinterpretation of manufacturer's parts catalogue and maintenance manuals, lack of coordination in the store's operating hours with the maintenance department operating hours, and inattention to the skills and training of storekeeping staff.

An effective materials management program is vital to the functioning of the maintenance department, yet many LDC ports mishandled these materials, or failed to exercise care in the consumption of costly items such as hydraulic oils and lubricants, which usually had to be imported and represented a large demand on foreign exchange. However, some ports were beginning to monitor individual machines and to link consumption with operating hours in order to better control the consumption.

Even in cases where some effort had been made to establish a maintenance program, the facilities used for maintenance purposes were usually substandard. The maintenance department was often relegated to whatever buildings happened to be available, and space and lifting facilities fell far short of being adequate. In addition, conditions were dirty and cluttered, and the maintenance tools and equipment supplied were unsuited to the work to be done.

A Recommended Approach to the Successful Management of Port Maintenance

It is clear that effective port management is the key to successful maintenance. It is realized that this management problem has its origins in the manner in which a government controls, regulates and constrains its ports. Three basic elements are required, in the Bank's view, to help countries initiate an understanding and appreciation of the maintenance function. These are:

- a concise document that presents the problem, the issues and how to overcome them, aimed at senior government ministry staff, the members of the port authority or the port board of directors, port general managers and heads of departments.

- a technical guide which provides in detail how to set up and manage port maintenance aimed at port general managers, operations and maintenance departments heads, and maintenance managers. (World Bank Technical Paper INU-57 could serve this purpose)

- training in port equipment policies, management and maintenance (an UNCTAD Policy Seminar IPP-3 of one week's duration held in the country but away from the port entitled "Port Equipment: Policy, Management and Maintenance" which is aimed at senior ministry staff, port board members, general managers, operations and maintenance managers is an appropriate training course for this purpose).

The basic content of each of these elements is the same - simply the time and detail devoted to each topic varies.
Port authorities or policymakers should not be discouraged from attempting to launch a maintenance program, even if their problems seem extensive or insurmountable. The disconcerting question for many is how to begin? Despite the enormous complexity of port maintenance problems, a few general principles can be identified as a useful springboard for action, whatever the size of the operation. These principles can be broken down into a number of key steps:

- **Define the maintenance problems**: The first step is obvious. The problems of port maintenance and their precise causes must be defined. Beyond an overview of the predominant and recurring problems of port maintenance and the reasons they tend to occur, one needs to start with an accurate analysis of what is going wrong and why in order to correct specific deficiencies. The corrective strategy, maintenance objectives over the long and short term, policy planning, equipment purchases and repairs, funding decisions, organizational reforms - all aspects of the hoped-for maintenance program will emanate from this core of known facts about the current operation. Most important, specific objectives concerning what the organization intends to become and what it intends to accomplish will be built around this core. This is where maintenance strategy begins to take shape.

- **Decide on basic maintenance strategy**: Maintenance objectives are by no means based on arbitrary decisions. They are governed not only by the current level of performance, but also by a variety of market, geographic, and political circumstances, coupled with the need to provide excellent service at exactly the right price. How, then, are specific maintenance objectives identified? The first point to note is that maintenance objectives fall into two types: broad and individual. The broad objectives are closely tied to the overall objectives of the port and the type of operation it intends to run; the individual objectives refer to what the maintenance department itself expects to accomplish. But these objectives, too, are closely tied to those of other departments, particularly operations. Since departmental objectives are interrelated, one broad objective of a maintenance program should be to achieve close interaction between the maintenance department and other port departments, but particularly operations.

  Second, objectives should be expressed in specific and measurable terms: for example, broad objectives might be expressed as an expected volume of traffic to be handled or cost per ton of cargo; while specific objectives might be expressed as "container vessels turnaround time with average of 150 movements should be achieved in 8.5 hours total" (for operations) and "demand availability of the straddle carrier fleet should be 95 percent". Such objectives provide standards that port management can strive to achieve and also use to measure the results of its actions.

  Objectives can also be classified by the type of activity they refer to, such as operating time or financial performance. For example, one goal may be not to keep container vessels waiting for berths longer than three hours, or to set handling rates for a first-generation container vessel at 20 moves per gross hour. Another goal may specify expected financial returns on fixed assets.
Whatever the objectives, it is important to remember that expectations must be reasonable and achievable. For example, it must be possible for a maintenance department to meet the demands of a specified turnaround schedule, or for a crane operating so many hours per day to handle a specified amount of cargo.

- **Formulate a Policy**: Once the goals have been identified, the next step is to determine how they can be accomplished. In other words, a policy must be formulated that defines the approaches and practices the organization will follow to implement its strategy. Again, port policy will cover many areas of operations. The principal areas that have a direct impact on equipment maintenance are: overall fleet management, fleet planning, traffic forecasts, calculation of the equipment workload, determination of required inventory levels, equipment replacement, procurement practices, spare part flows and technical training. Procurement policy, for example, may specify the agencies that need to approve a proposed expenditure (in some of the countries surveyed, ministerial approval is required), or restrictions on the level of expenditure (some ports are required to purchase the lowest-priced equipment, without regard to maintenance performance, fleet standardization, or service capability).

At times, there is almost an unlimited number of options available to the port in supplying equipment needs. Therefore port staff need direction to avoid spending undue time evaluating options or taking faulty courses of action. When a number of departments are involved in procurement, policies should be designed to ensure that all departments pull in the same direction. Other questions that policy statements should address include when to buy off-the-shelf equipment and when to buy custom designed equipment; the quantity of spares that should be purchased with equipment (and how to arrange this at the time of equipment procurement); whether local manufacturers should be encouraged to manufacture spare parts, and if so, under what conditions (e.g., only when they can obtain a license from the original manufacturer, or never when the equipment is still under warranty); what situations require competitive bidding; how to fill standing orders; or what entity should have responsibility for determining bid lists and preparing bid documents, and what procedures to follow in bidding and bid evaluation.

In the last case, the basic approaches to the selection of suppliers for bid invitations should be spelled out, and the bid evaluation procedures should be defined. (e.g., conduct detailed review of equipment performance capabilities to ensure that they meet the port’s requirements; conduct in-depth analysis of supplier performance with respect to spare parts and technical services, past performance with the port, with other ports, and other users of the equipment; and conduct in-depth analysis of technical support, how much maintenance is usually required of the supplier’s equipment, and whether components are compatible with other equipment in the fleet). Whatever aspect of port activities the policy covers, it must be clearly stated and communicated to port staff and systematically implemented. Equally important, adequate budgets must be created so that funds are available to carry out these policies.
Funding and management of maintenance costs: If maintenance is not funded at an adequate level, port equipment will deteriorate, cargo handling rates will decline, and the revenue earned by the port will be reduced. However, port maintenance can be a costly activity. A container crane, for example, costing US$4.5-5.0 million, will have maintenance costs in the neighborhood of $170,000 a year. Spare parts may represent as much as 45 percent of these total maintenance costs, and in most cases in foreign exchange. The ports themselves generate foreign exchange, since the port tariff and charges structure normally requires payment for certain services in foreign exchange. The port should be allowed to retain sufficient funds from this source to cover essential spare parts and, if possible, equipment replacement. A revolving account could be considered. The size of the account will depend on various factors: realistic estimates of revenue over extended periods of time; realistic estimates of spare parts requirements extended over periods of time and typically converted to an annual requirement; and realistic equipment replacement plans. If these factors are known, it is possible to construct revenue-retention ratios that will provide sufficient, but not excessive revolving funds.

Whatever the source of funds, port management must set up strict procedures to ensure adequate and accurate budgeting and disbursement against specific expenditures. The budget itself should be an expression of a plan in monetary and physical units, and it should represent a condition that can reasonably be expected to happen. Consequently, budgeting should begin with an overall port development plan prepared in detail for at least a one-year period. A port should also have a longer-range plan, one that covers a period of perhaps five years. The short-range plan usually includes the number and type of ship operations; the number of cargo units to be handled, by type of unit and type of handling operation; and the number of operating hours for each type of equipment. By applying standard service factors to this plan, the port should be able to develop a maintenance plan for each week of the year, covering factors such as the demand availability and maintenance efficiency expected for each type of equipment, hours expected in overhaul, modification or capital addition projects that will be performed by the maintenance department, maintenance manpower required for work detailed in the plan, an estimate of the cost of material required, an estimate of the cost of maintenance department labor, and so on. Maintenance will probably be the largest single item in the budget - about 25% of the port's revenue - of a typical port.

One of the difficulties in preparing a port budget is how to cope with the large differences that very often occur between actual conditions and those that were anticipated when the budget was prepared, for example, in the volume and type of cargo to be handled, or in the type of vessel to be serviced. One possible solution to this problem is the flexible budget, which provides department managers with a means of diverting available resources to different purposes when the port's traffic patterns vary from the original expectations.

To control costs, the port must first establish a data system to identify the exact costs that have been incurred and in what areas, notably labor, materials, purchased services, maintenance department overhead, for
each unit of equipment, each work order, and components. Costs are controlled by monitoring the physical resources and activities of the organization. Work performance is directly controlled by the supervisor. Therefore, each port must establish the precise limits of authority that will apply to each department head, including the manager of the maintenance department. The maintenance manager will, in turn, delegate portions of this authority. This does not mean that the maintenance department should be given a free hand in spending decisions, but a certain degree of authority within the framework of a specific plan or budget. The ultimate objective of maintenance should be to achieve high-demand availability and maintenance efficiency, coupled with low maintenance costs. That efficiency will be difficult to achieve without a strong organizational structure and a good data/information system.

Organization: Ideally, each employee in an organization should know what is expected of him and be accountable to his superior for the actual results, as measured by what was expected. This principle of accountability should apply to managers and supervisors as well as technicians, and it should be part of everyday procedures. Accountability starts at the top. The port managing director should be accountable to the commission or board that governs the port, and his subordinates, in turn, should be accountable to him for the management of the maintenance program.

Accountability is one of the most important principles underlying the organizational structure of a successful port. Therefore, when duties and responsibilities are being assigned to various positions in a port, the following guidelines should be kept in mind: (1) responsibility for results should not be divided between different departments in the organization (for example, it would be a mistake to put the operations department in charge of preventive maintenance while asking the maintenance department to manage the predictive maintenance and repairs of the same equipment); and, (2) responsibility and authority must be in balance. The person assigned a certain responsibility should have the authority to carry out the work. An organizational manual is a useful method of establishing and communicating these organizational concepts.

As already stated, interaction between the operations and maintenance departments is clearly important for organizational harmony. The key to success is joint planning, scheduling, and coordination. Harmonious relations do not simply happen. Furthermore, senior management must recognize the operational and economic importance of the maintenance department. All too often, the operations department is considered to be the "earner" while maintenance is considered a service group. The most successful ports have recognized the importance of upgrading the status of maintenance, especially mechanical equipment maintenance.

Another critical step in undertaking a maintenance program is to decide how to reorganize the maintenance department. In many ports, two management levels are sufficient in the maintenance department. In very large organizations, three levels (Maintenance Manager, General Foreman, and Front Line) may be required. Remember, however, that excessive layers of management impede communications between management and craftsmen, cause delays, and reduce motivation in general. In fact, in many ports maintenance management
is too far removed from the technicians, and managers tend to lose touch with the realities of the workplace. These realities can also be faced better when the departments of an organization participate in joint planning, scheduling, and coordination. Operations and maintenance will find it useful to hold regular planning meetings together to work out specific equipment maintenance schedules.

- **Maintenance Implementation: In-house or Outside Contractor:** A very important decision to make in introducing a maintenance program is how much maintenance should be performed by the port’s maintenance department. In the case of fork lift truck engines, for example, one level of maintenance would be preventive (i.e., lubrication, checking of fluids, inspection, changing hoses and filters, etc.); another would cover replacement of parts, and a third might consist of a complete rebuilding of the engine.

If certain tasks are outside regular port maintenance activities or are performed infrequently, they should possibly be assigned to an outside maintenance contractor. For instance, a port with an average of 12 diesel engines to be rebuilt each year will likely call on an outside contractor for this work. On the other hand, if a port is called upon to rebuild 60 engines a year, it might consider establishing a rebuild shop in-house. When making the decision to use an outside contractor for maintenance work, a careful evaluation must be made of the in-house option versus the contractor to determine which is most cost-effective and what skills are required - and whether they are available within the port organization. Even if a contractor is used, however, senior port management and maintenance must recognize that it is still their responsibility to ensure that the work is done properly and economically. Therefore, a member of the port’s maintenance department, with appropriate skills and authority, must be made responsible for coordinating and managing all aspects of the maintenance contract.

- **Introducing the maintenance program:** When a maintenance program is to be implemented, a number of changes will have to take place in the way that management, supervision, and planning are handled in the maintenance department. The program must have the full support and backing of the port’s management if it is to succeed. In some cases, it may be necessary to provide technical training or to upgrade workshops and other facilities in order to get the program under way. These and any other desired features of the program should be listed at the outset of the planning stage. Here are several other steps to include in the implementation of such a program:

  - Identify existing features to be retained: Introducing a new maintenance system implies major changes in the way things are done. Procedures that work well at present should be retained if they can be incorporated into the new system. The amount of change should be kept to a minimum.

  - Prepare a conceptual description of the system: This description should briefly describe how the system will work, what it will do, the reports it will produce, and how it will affect each level and each department of the organization. Specify whether the program will cover both preventive maintenance (i.e., activities intended to prevent catastrophic equipment failure, undetected wear, premature failure, and
substandard equipment performance) and predictive maintenance
(activities applied to equipment components that encounter wear or
stress at a constant rate).

- **Select data-handling method:** Select the method that will be used to
handle data and make calculations. If a computer approach is to be
used, select the computer and software, remembering to keep the system
as simple as possible.

- **Prepare a detailed work plan:** Identify each task that must be completed
and who will perform the task, estimate the time required for each task,
and organize the sequencing of tasks in a workable schedule.

- **Estimate the time and costs of implementing the system.** Implementing a
maintenance management system will represent a significant expenditure.
It is better that management knows this in advance.

- **Assign responsibility and duties for operation of the system.**

- **Train staff to undertake the maintenance tasks.**

- **Provide staff with a maintenance manual that covers organizational
structure, individual job performance, and maintenance strategy, policy,
and procedures.**

- **Monitor the execution of the system closely.** Take corrective action
where necessary. Continue close monitoring until the program has been
operating smoothly for at least one year, with periodic reviews
thereafter.

The steps outlined above represent a systematic approach to managing
maintenance. Few LDC ports have yet recognized the importance of approaching
maintenance in this way. Little effort is put into measuring the
effectiveness of maintenance, to establish what corrective action is needed
when a problem arises, and to take the final results into account in future
plans. Thus, few LDC ports have truly comprehensive maintenance programs that
cover all aspects of maintenance: operating plans and budgets, coordinating
maintenance with operations, collecting operating statistics, work order
needs, work history, standards of expectation, performance monitoring,
preventive maintenance, predictive maintenance, component tracking, spare
parts needs, material control, failure analysis, or warranty control. Until
maintenance is viewed from such a well managed and programmatic perspective,
performance in LDC ports will continue on its present course of apathy and
poor productivity.
I. INTRODUCTION

1.0 The Problem

There are many difficult problems facing the port managers in less developed countries (LDC’s), but perhaps the most difficult is the management of port maintenance. Unavoidably, even the smaller ports have a large investment in port mechanical equipment and an even larger investment in infrastructure; all of which requires continuous, timely and effective maintenance. In many ways infrastructure maintenance can continue to function for a number of years in an atmosphere of almost complete neglect but mechanical equipment is very different. Unfortunately, as ports struggle to meet the demands of the ship operators, they have to acquire more complex cargo handling equipment and thus the maintenance task is steadily becoming more difficult.

A port’s equipment and infrastructure have to be kept in a condition so that it is readily available when needed by the operations staff. Inability to meet these demands results in poor service, delays, increased charges and frustration leading to major economic costs. In terms of maintenance the following categories need to be considered:

- mechanical equipment for cargo handling or other operations
- floating craft
- electrical installations
- dredging
- infrastructure/civil works
- navigation aids

This listing puts the categories in order of difficulty to resolve - mechanical equipment being the most difficult task for most ports.

1.1 What are the causes of the problem?

Of the many factors which create the maintenance problem the following are the more important:

i) Management inadequacies: Failure of the port’s management to recognize the extreme importance of the maintenance function and consequently to provide an adequate budget, facilities and staffing. Also, finding well trained, experienced maintenance managers is extremely difficult in most LDC’s. Such skills are rare and the level of salaries, benefits and other conditions is a key issue for recruitment and retention.

ii) Lack of a proper relationship with port operations: In many ports there is a chronic dichotomy between the operations manager and the maintenance function because there is no planned coordination between the two. Usually, the demands of the port operations function prevail with consequent damage to the equipment and demoralized maintenance
iii) Lack of free access to foreign exchange: While this does not apply to all LDC ports, it is a major problem for many of the poorer countries. The scarcity is reflected in lack of sufficient spare parts, special materials, lubricants and the inability to employ foreign technicians for complex tasks when required.

iv) Poor salary levels and rates of pay: This results in the port being unable to attract staff at all levels with appropriate training and experience. It also results in failure of training schemes and technical assistance programs since the newly trained staff tend to leave for better paid positions outside the port. This can be a costly exercise for the port. Effective maintenance will be impossible to achieve unless a well managed cohesive, motivated team of engineers, technicians and staff is created who have some pride in working for the port.

v) The maintenance environment: Effective maintenance can only be carried out under the right conditions. The quality of the port's workshops, servicing areas, stores and staff facilities must not only be appropriate for the tasks but also create a feeling of pride and responsiveness.

vi) Regard for the useful life of equipment: Very often, too much effort is expended on attempting to keep time expired equipment operational without regard for the costs involved - sometimes on the misguided principle that this will save scarce foreign exchange. Many ports in LDC's have outmoded legislation that makes it difficult to dispose of old equipment and hence there is a tendency to try to keep it going.

vii) Too many different makes of similar kinds of equipment: The ports of LDC's find it difficult to concentrate on a few manufacturers - largely as a consequence of the sources of funding. Thus the maintenance task is made more difficult than in an industrialized country because of the need for increased training, more manuals and stocks of spare parts.

viii) Poor quality of the working surfaces over which the equipment has to operate: In many LDC ports, lack of infrastructure maintenance results in equipment having to operate over very rough pavements (especially where there are railway tracks) in the stacking areas and transit sheds resulting in excessive damage to the equipment and also cargo.

ix) The lack of adequate data: The failure of the port's management to demand and ensure the collection and presentation of essential data makes equipment control and condition monitoring very difficult. The lack of such systems makes it next to impossible to set appropriate budgets, provide adequate staffing, arrange coordination with operations, and procure spare parts in an effective manner.

There are other difficulties which vary from country to country and port to port and many of these are discussed in the paper.
CAUSES OF EQUIPMENT SHORTAGES

The cause of equipment shortages is not necessarily the failure of the port to purchase enough units. Inadequate maintenance is the root cause. The UWIST survey demonstrated the magnitude of the problem. This table shows average daily "availability" data for ports in one of the countries surveyed, arranged under the four headings (the terms used are those of the ports concerned): the inventory level (units currently listed in the ports' inventory); units "serviceable" (considered by the engineers as being—nominally, at least—capable of being maintained and used); units "under maintenance" (either currently in the workshop or awaiting spare parts); and, those "available" (units in working order and fit for allocation to the berths).

The most striking point to emerge is the extremely small proportion of inventoried units that were listed as "available". For example only 15% of the total stock of forklift trucks were, on average, "available" for use at any one time during the period surveyed, and only 42% of them are actually still considered capable of being maintained ("serviceable"). The explanation for these extraordinary figures is that equipment is retained on the asset register well beyond its physical life, and a very high proportion of the rest of the stock is undergoing repair, often because of accidents resulting from bad driving. Many of the "unserviceable" units had been heavily cannibalized in an attempt to keep other units in a maintainable state.

<table>
<thead>
<tr>
<th>Type of Equipment</th>
<th>Inventory Level</th>
<th>Number &quot;Serviceable&quot;</th>
<th>Number &quot;Under Maintenance&quot;</th>
<th>Number &quot;Available&quot;</th>
</tr>
</thead>
<tbody>
<tr>
<td>Portable Cranes</td>
<td>70</td>
<td>53</td>
<td>24</td>
<td>29</td>
</tr>
<tr>
<td>Mobile Cranes</td>
<td>77</td>
<td>36</td>
<td>25</td>
<td>11</td>
</tr>
<tr>
<td>Forklift Trucks</td>
<td>467</td>
<td>199</td>
<td>127</td>
<td>72</td>
</tr>
<tr>
<td>Tractors</td>
<td>100</td>
<td>65</td>
<td>51</td>
<td>14</td>
</tr>
<tr>
<td>Trailers</td>
<td>243</td>
<td>94</td>
<td>40</td>
<td>54</td>
</tr>
<tr>
<td>Berthing Tugs</td>
<td>8</td>
<td>6</td>
<td>5</td>
<td>1</td>
</tr>
<tr>
<td>Lighters/Pontoons</td>
<td>107</td>
<td>71</td>
<td>56</td>
<td>15</td>
</tr>
<tr>
<td>Lighter Tugs</td>
<td>14</td>
<td>10</td>
<td>6</td>
<td>4</td>
</tr>
<tr>
<td>Labour Launches</td>
<td>17</td>
<td>14</td>
<td>9</td>
<td>5</td>
</tr>
</tbody>
</table>

1.2 How can the problem be overcome?

The Bank considered that a set of guidelines were needed both for the use of the Bank's staff engaged in lending operations for ports and harbours and also for the staff of the Bank's borrowers. Because the root of the problem lies with government, it was established that a set of basic guidelines which could be easily read by senior government officials relatively unfamiliar with port activities was required as well as much more detailed guidelines and supporting documents for the port management, operations and maintenance staff. These documents would spell out how to approach the maintenance problem and to resolve it. It was also agreed with UNCTAD that a training seminar using the same materials was also a necessity to ensure that the message is properly received.

1.3 The background to this technical paper

Although the factors spelled out in 1.1 above were well known to the World Bank, it was decided to commence the preparation work with a survey of ports where maintenance is well managed but also to include a few ports where maintenance is known to be a serious problem. It was felt that such a survey would better indicate the extent of the problem, the root causes of poor
maintenance, how ports are able to overcome these problems and the type of action that is needed. The survey was awarded to a team of experts managed by the Department of Maritime Studies, University of Wales Institute of Science and Technology (UWIST) and financed by the UK Department of Trade and Industry. The survey was made early in 1988 and covered the following ports:

European ports: Felixstowe; Grimsby; Immingham; Southampton; Port Talbot; Bremmerhaven; and, Antwerp.

LDC Ports: Alexandria; Dar-es-Salaam; Madras; Bombay; Colombo; Singapore; Penang; Buenaventura; Santa Marta; and, Cartagena.

1.4 The findings of the survey

If there were any doubts as to the seriousness of the maintenance problems facing many of the LDC ports, they were dispelled as a consequence of the survey. Maintenance deficiencies have been found to exist in all port activities - infrastructure, floating craft, electrical systems - but there was ample evidence that they are particularly severe in relation to mechanical equipment. There are several LDC ports where maintenance is well managed and where operational and engineering standards are excellent, but there are others where selective - and even relatively minor - improvements would yield significant benefits in improved maintenance, better control and lower costs. However, in a large number of ports, more profound changes are needed since maintenance has reached a crisis point. It is in these ports, where the problem is endemic and acutely serious, that the major challenge occurs.

Commonly, the maintenance problem is attributed to technical inadequacies, shortcomings in the engineering departments and lack of spare parts, and that improving the staffing and equipment of the workshops would solve - or significantly alleviate - the difficulties. Thus, it is particularly striking that a major finding of the survey showed that the root of the problem lies in institutional, administrative and managerial areas: particularly government/port relationships; control and regulation; poorly formulated government/port policies and objectives; constraints imposed by

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1 The team was headed by Dr.B.J.Thomas, Senior Lecturer, and comprised: J.H.Northfield, Engineering and Technical Services Director, Port of Felixstowe; E.E.Pollock, Managing Director, Associated British Ports Research and Consultancy Limited; and, D.K.Roach, Managing Director, Interface 4 Limited. J.R.Lethbridge, Ports Advisor, World Bank, covered the Colombian Ports.

2 UWIST; from September 1988, incorporated within the new University of Wales College of Cardiff.

3 UK DTI; Projects and Exports Policy Division.

4 The full findings of the survey have been published by, and may be purchased from, Her Majesty's Stationery Office, UK, as a report entitled "Management of Port Maintenance - A review of current problems and practices" 245 pages, 1989.
central planning bodies; and, failure to recognize the significant costs of maintenance and to provide appropriate budgets both at government and port levels. Rarely was the technical competence of the engineering staff the most evident explanation for poor maintenance.

Other findings revealed inappropriate port organizational structures, inadequate planning mechanisms. Especially important is the relationship between port operations and the maintenance staff. The position of the managers of these two major sections of the port's activities within the overall port organizational structure is very critical. In many ports the maintenance manager is unable to manage effectively and is frustrated through lack of power. A major finding was the almost universal lack of detectable employee motivation. Many of the staff have negative attitudes towards their jobs and the port - poor maintenance was invariably associated with a human resource crisis.

Many of the ports had inadequate, unreliable and fragmentary management information systems and, particularly, poor maintenance and equipment performance data systems with the result that decision making is not based on sound reasoning. Especially lacking was information on the costs of maintenance. Managers seemed unaware of the fact that more money will be spent on maintaining equipment than was used to purchase it in the first instance.

In summary the more important findings were:

- Failure to adequately fund maintenance both in local currencies and especially foreign exchange
- Failure to set performance targets
- Lack of delegation and accountability
- Inadequate planning and control procedures
- Poor cooperation between operations and maintenance
- Maintenance managers basically unfamiliar with the realities at the level of the workshop floor.
- Poor salaries and rates of pay
- Inadequate training
- Lack of motivation and pride in working
- Slow response to operational needs

All of these issues are discussed in detail in the following chapters.

1.5 The costs of inadequate maintenance

The availability and reliability of equipment seriously affect the efficiency and costs of cargo handling operations and thus the costs of goods passing through the port. In particular, because of slower ship turn around times, shipping lines directly reflect the inefficiency in increased rates. Thus the problem influences the country's ability to compete in the export market on a basis of final cost of goods.

Equipment maintenance costs range from 15% to 25% of the port's total operating expenditures and is frequently the port's largest single item of
expenditure - with a significant proportion in foreign exchange depending on the country.

Figure I-1

To illustrate the magnitude of the impact which maintenance can have, an actual case history is included. Figure I-1 displays the dramatic reduction in maintenance costs per unit of production which one material handling operation was able to achieve when they improved maintenance performance. The benefits came about through increased output resulting from less equipment down time and through reduced expenditures on maintenance.

### AVERAGE EQUIPMENT OPERATING COSTS OF CONTAINER-HANDLING EQUIPMENT AT AN LDC PORT (in US$/Unit)

<table>
<thead>
<tr>
<th>Equipment</th>
<th>Annual Running Costs</th>
<th>Annual Maintenance Costs</th>
<th>Total Annual Operating Costs</th>
<th>Annual Operating Hours</th>
<th>Hourly Operating Costs</th>
</tr>
</thead>
<tbody>
<tr>
<td>Container Crane</td>
<td>97,467</td>
<td>60,963</td>
<td>158,430</td>
<td>3,500</td>
<td>45</td>
</tr>
<tr>
<td>Straddle Carrier</td>
<td>44,732</td>
<td>34,255</td>
<td>78,987</td>
<td>1,400</td>
<td>56</td>
</tr>
<tr>
<td>Rubber-tyred GC</td>
<td>54,312</td>
<td>27,468</td>
<td>81,780</td>
<td>2,000</td>
<td>41</td>
</tr>
<tr>
<td>Terminal Tractor</td>
<td>31,482</td>
<td>10,890</td>
<td>42,372</td>
<td>1,800</td>
<td>24</td>
</tr>
<tr>
<td>Front-end Loader</td>
<td>29,709</td>
<td>22,654</td>
<td>52,363</td>
<td>1,500</td>
<td>35</td>
</tr>
<tr>
<td>Forklift Truck</td>
<td>18,960</td>
<td>5,966</td>
<td>24,926</td>
<td>1,200</td>
<td>21</td>
</tr>
</tbody>
</table>
Effective port maintenance is expensive and requires proper funding. Later in this report, figure 3.01 in Chapter 3.0 indicates that the annual expenditure for maintenance of cargo handling equipment may range from 3% to 17%, or more, of the equipment replacement cost. Of that, as much as 45%, or more, may consist of spare parts expenses, requiring foreign exchange.

1.6 The objectives of this paper

The objectives are to help governments and ports overcome their present difficulties in keeping expensive equipment operational. It is considered that the essential first steps towards this goal are:

- to provide a document that is short and easily read by senior government officials downwards through port authorities to port managers that establishes the importance of a well managed, properly funded port maintenance function; and,

- to provide a detailed guide for the use of the port's management on how to achieve effective maintenance.

- to provide a seminar on how to implement an effective maintenance management program

A set of World Bank Guidelines (an executive summary of this paper) will satisfy the former need, and this Technical Paper is intended as the detailed guide for the use of the port's management.

The background material to this technical paper as well as the paper itself forms a major part of the UNCTAD IPP-3 Policy Seminar entitled "Port Equipment: Policy, Management and Maintenance". This one week seminar aimed at senior government officials associated with the transport sector as well as port board members and managers is now available through application to UNCTAD's Port Section, Shipping Division, in Geneva, Switzerland. The seminar was validated in Kingston, Jamaica, in December 1989 with participants drawn from several Caribbean countries.
II. GOVERNMENT POLICY AND INSTITUTIONAL CONSIDERATIONS

In the context of on-going macro-economic reforms in many less developed countries a major objective is to make parastatal activities, including ports, increasingly self-sufficient and cost effective so as to ensure their efficient contribution to production and growth. Efficiency and productivity depend on competent management decisions involving matters such as staffing, salary and employment practices, financial policies, port charges and tariffs, investment planning, quality of service, etc., which are all areas in which government intervention has been common. Financial discipline, deregulation and increased commercialization, labor policy planning and equipment maintenance management are some of the more relevant means to improve efficiency. Port management must be subject to the discipline of financial performance, have the clear authority to make decisions and be accountable for them. For many ports, the existing statutes of incorporation, the roles and responsibility of the Board no longer adequately reflect the reality of relations between the government and themselves. If these ports are to be allowed to operate as commercial entities there is a need to review existing regulations, legislation and controls.

Governments in both industrialized and developing countries are experimenting with institutional reforms to separate port management from ownership. The trend towards increasing use of the private sector, with their apparent superior operational efficiency, results from handicaps imposed on public sector ports through government intervention under which they are expected to perform and which may be difficult to reform quickly. There is a clear need to carefully balance the use of the private sector with the provision of complete autonomy to the port.

The scope of maintenance work performed by ports varies considerably. In some situations the port or port authority maintains all the facilities from marine craft to civil works to cargo handling equipment. In other cases the port authority is primarily a "landlord" with the facilities and equipment being operated and/or maintained by an independent entity, which may be either public or private. Most ports represent varying degrees between these two approaches.

The approach used does not change the importance of the maintenance function. Poor maintenance performance will have the same negative impact on the national interests regardless of which institution performs the work. Therefore, it remains a primary responsibility of the port to ensure that maintenance is performed effectively even if others perform the work. This assurance should be dealt with in the inter-institutional contracts (leases, etc.), setting out clearly the performance results expected, giving the port authority the power to examine results, and defining remedies if results are less than expected. The port authority and government agencies should not, however, fall into the trap of "controlling the activities" of the operating institution. Control should be based strictly on results.

A most significant finding of the UWIST survey is the extent to which institutional and organisational factors affect the ability of LDC ports to
establish and sustain an efficient maintenance function. In most LDC ports surveyed, there are extremely close and strong links between relevant government ministries and port organizations. These links greatly affect, and often impede, the ports' ability to manage their maintenance and operational functions, negatively impacting results.

Government control often takes the form of interference in the day-to-day activities of the port. One of the alarming impressions received, from the survey, is that in several developing countries this interference is actually on the increase. In European ports, however, there is a trend toward increasing port autonomy. Most North American ports have traditionally operated with a high degree of autonomy.

An example of controlling activities might be approval, by the responsible ministry, of individual purchase orders for spare or replacement parts. On the other hand, under the control of results approach, the port would have an approved budget for purchase of such parts. They would be free to place orders for parts, as long as they can stay within the budget. If it became apparent that it would become necessary to exceed the budget, the port would submit a proposal for budget modification, or some other alternative, to the ministry. The ministry could then examine the alternative actions available and agree, together with port management, upon a course of action. In this way the ministry focuses on results and the port staff perform the activities.

Regulations may appear reasonable, but the actual enforcement can become unreasonable. Senior officials need to look beyond the written procedures to find out what is actually happening.

Government control of LDC ports is generally centered in the following areas. They are mentioned briefly here, but are discussed in more detail in later chapters (numbers in brackets, indicate the chapter reference).

2.1 Long Range Planning. (4.1 and 12.2) Five year plans, covering traffic, revenue, operating costs, capital costs, etc., are commonly prepared and submitted to government. Long range planning is an appropriate activity for the management of a port.

Some governments, however, require a fixed five year plan which remains in force, as the official operating plan, during the full five year period. The reality of port management is that conditions such as international trade patterns, traffic volume and mix, material prices, exchange rates, etc. cannot be forecast with any degree of certainty that far into the future. A recommended approach is to apply a five year rolling plan concept. Each year the first year of the plan is developed in detail and subsequent years are developed with broader criteria. In that way the port has the opportunity to modify the plan and adjust budgets as conditions change.

Plans, once developed and approved, should then be left to the line agencies to execute. There is always a risk that the government central planning units will exercise some control over execution of the plans.
While this is well intentioned, there is a negative impact in that the balance between responsibility and authority is distorted. The line agency, in this case port management, should be given the responsibility and authority to execute the plan. If they do not have the authority, they cannot be held accountable for results, and one of the primary motivators is lost.

2.2 Expenditure Controls. (4.3 and 13.0) LDC ports commonly work under inflexible investment controls which result in the port being unable to respond to changes in traffic demand. As a result, the cargo handling equipment does not match the cargo to be handled.

Similarly, controls on importation of spare parts cause long delays in completing repairs of equipment and require excessive investment in spare parts inventory.

Governmental reduction of these activity based controls is essential to the effective operation and maintenance of LDC ports. Certainly the limited supply of foreign exchange, which is a reality to most LDCs, will be a factor. It is recommended that port revenue charges be structured so that the port has the opportunity to generate sufficient funds to support its operational and capital needs. Then the port should be allowed to retain, in its own reserve funds, a sufficient portion of the revenue to provide the necessary foreign exchange. To be effective, the port must have autonomous control over these reserve funds and expenditures.

2.3 Port Revenue Charges. (5.0) Some governments restrict port management from reviewing and revising port charges on a timely basis. Ports must have the freedom to establish port charges in much the same manner as would a private commercial enterprise; i.e. recognizing market and cost factors. However, it is important to recognize the monopoly position that many ports enjoy and the temptation to set charges at what the market might bear. Thus there must be a national body to ensure that charges are reasonable but, at the same time, do not constrain the port in carrying out its task efficiently.

2.4 Procurement Controls. (4.3) LDC governments were often observed to place very specific restrictions on procurement policies of the ports. In some cases, this has the effect of causing extensive delays in purchase of parts, materials, or equipment. It also often results in purchase of equipment not suitable for the job or in fleets of non-standardized equipment, all resulting in a negative impact on results.

Ports must have the ability, within established guidelines, to function with substantial autonomy in the procurement area if they are to maintain equipment effectively and provide an acceptable level of service to shippers.

2.5 Employment Policies. (4.3) Restrictions, aimed at conforming port policies to governmental policies, often make the port unable to offer employment conditions which will attract and retain competent and
energetic personnel. The port must be able to compete with private enterprise for the most qualified people. Port management can best determine the policies which will accomplish that end, while optimizing results.

2.6 Approval of Specific Activities and Transactions. In some cases government civil servants have the power to veto specific activities of the port, such as issuing a purchase order. Invariably the civil servants with such power do not have the knowledge necessary to make the best decision.

Occasionally, the government ministry responsible for the port places one of their employees directly into the organization of the port. The only observed advantage of this approach is an improved ability of the port to anticipate the ministry's priorities.

It is strongly recommended that the government ministry should control the port through strategies, plans, objectives and results, not by controlling day-to-day operational activities. Control of activities will often result in inappropriate decisions, substantial delays, and most importantly it will, without fail, stifle initiative and enthusiasm throughout the port organization, all negatively impacting results.

The port's interaction with government policies and regulations should take place through the sponsoring ministry or department. The sponsoring ministry will understand the specific needs and problems of the port whereas other ministries and central planning units will be unable to develop a detailed understanding, because of their involvement with all of the different activities of the government departments and agencies. Furthermore, the sponsoring ministry bears the responsibility for the success or failure of the port even though other ministries may benefit directly from the activities - ministry of trade, for example. It is for the sponsoring ministry to ensure that the port is able to operate efficiently and that the regulatory and institutional structure is appropriate.

The government should stimulate the development of a port organization that effectively operates in a commercial manner emphasizing responsibility and accountability and the means to measure performance. This latter point is very important - only if the levels of performance are known and can be related to achievable levels can the necessary corrective action be taken.

An important consideration is the appointment of a chairman and the make up of a board of directors responsible for controlling the activities of the port. A clearly independent chairman, with a board composed of owners, users, shippers, the community and other major interests is recommended.
III. STRATEGY

"Strategy" is a way of stating what an enterprise or organization intends to be and what it intends to accomplish. For example, a port may determine that it is to be a load center transhipment port, such as Singapore, or it may be a single bulk commodity port, etc. This determination, of course, is not an arbitrary decision. It is affected by a variety of market, geographic, and political circumstances coupled with the need to provide excellent service at exactly the right price. It is important that the port wisely recognizes all of these circumstances and establishes a strategy which can realistically be accomplished. If not, the likely result will be:

- A port with facilities and procedures which do not meet the realities of the ship operators needs and the freight markets, and
- Poor financial results.

Less developed countries cannot afford the expensive luxury of over-capacity.

The second part of strategy, what it intends to accomplish, is usually expressed in the form of objectives. In the paragraphs below, we will discuss objectives at various "levels". First are the broad objectives of the port, which must be consistent with the "what we intend to be" statement. Once these objectives are established, individual departmental objectives can be established. Departmental objectives represent the "strategy" of the individual department.

The way in which the port accomplishes the objectives is expressed through its policies. Policies are discussed in section IV.

3.0 Objectives

Objectives should be expressed in specific and measurable terms. If they are, they become a clear set of standards which port management strives to achieve and against which actual results are measured. They serve to keep management "on course" as well as motivate management and staff.

To serve this dual role, objectives must be reasonably attainable and must be enthusiastically "believed" by port management. Therefore, it is a primary rule of management that objectives should be jointly established by the superior and subordinate persons involved. That is to say that the responsible ministry and port top management should jointly establish the port's broad objectives. Both must agree that the objectives are appropriate and attainable. Objectives unilaterally established from above will be ineffective.

3.1 Overall Objectives

Overall objectives might be expressed in terms of a percentage return on fixed assets, volume of traffic to be handled, cost per ton of cargo, etc.
One of the more disturbing findings of the UWIST study is that many LDC governments and ports have not set clearly defined financial or performance goals. Where such objectives were established, they were vague, poorly defined, or unrealistic.

One port had established an objective of 6% return on net fixed assets. Due to inflation, this only amounted to 1% on asset replacement value; clearly an inadequate commercial return. In another case a port was expected to return 25% of surplus funds to the government as a deemed dividend on top of a 50% tax on the surplus plus having to service three major foreign currency loans. These were very clear objectives, but unrealistic. There simply were not sufficient funds to allow proper maintenance of equipment and timely replacement. Such objectives result in a general decline of port equipment, ending in a continuing reduction of financial return.

Financial objectives must be established so that port management has sufficient funds, both foreign and domestic, to conduct its operations properly. Without sufficient funds management loses their initiative and motivation. The port will operate with substandard performance.

Another finding of the UWIST study was poorly motivated maintenance forces in most LDC ports. Improved staff motivation should be high priority objectives of port management. Once again, the objectives should be expressed in measurable results, such as "Absenteeism at 3.5%, or less".

3.2 Operations Objectives

Operations objectives should include specific vessel and cargo handling performance standards. One Asian port has set its performance goals as:

- No delays to container vessels.
- Container carrying road vehicle turnarounds within 30 minutes of arrival.

Another port set the following objective standards:

- Container vessels turnaround with average load of 150 movements - 8.5 hours gross.
- Conventional vessels turnaround with average load of 1000 tons - 30 hours.
- Container vessels waiting for berth not to exceed - 8 hours.
- Conventional vessels waiting for berth not to exceed - 16 hours.
- Handling rates for first generation container vessels - 20 TEUs per gross hour.
Handling rates for second generation container vessels - 25 TEUs per gross hour.

These are but a few examples of objectives set by that port. Interestingly, they went one step further, and specified concrete actions which were to be taken to make possible the achievement of these goals.

Since the size of the fleet of cargo handling equipment is affected by the manner in which the operating department utilizes the equipment, they should establish an objective for utilization of each type of cargo handling equipment. See Figure 3.3.1 for a definition. Similarly, production rate targets should be set for each type of equipment.

Operations performance objectives should be based on the specific sizes and types of equipment, the labor force, types of ships, and traffic patterns which will actually come into play at the port in question. As an example, one port may determine that a 30 ton container crane will make an average of 20 moves per hour while another port may find their realistic average will be 18.

Operations standards are discussed both here and later in this paper, because they will have a direct impact on objectives which the maintenance department must achieve. Maintenance objectives should be established such that they are compatible with operations objectives. Conversely, operations objectives must not place demands on maintenance which cannot be met.

3.3 Maintenance Objectives

The maintenance objectives will support the operations objectives. For instance, if operations has a no delay to container ships objective, the maintenance department would set 100% as the Demand Availability (sometimes called Reliability) objective on the container crane.

The UWIST study concluded that maintenance is now the biggest obstacle to achieving satisfactory cargo handling performance in many LDC ports. Therefore, this question of maintenance department objectives and their relationship to operations objectives should receive the attention of top port management.

Examples of objectives which are typically appropriate for a port maintenance department include:

- Demand Availability of Straddle Carrier Fleet 95%
- Demand Availability of Individual Container Crane 100%
- Maintenance Efficiency of Straddle Carrier Fleet 75%

5One word of caution; these standards are included here as examples. They will not be appropriate for every port and should not be interpreted as industry standards.
Other objectives may deal with accident and injury rates, mean time between overhauls, preventive maintenance performance, overtime rates, absenteeism rates, etc.

Availability, efficiency and utilization indices are calculated in a variety of ways. The formulas in Figure 3.3.1 are recommended.

In Figure 3.3.1 the quantitative data are included for illustration purposes. The Total Hours, 168, represent one week 24 hours per day for one crane. Crane demand of 80 hours was determined by the arrival of ships and requirements of the operating department. This time requirement was also influenced by the down time for maintenance during time periods when there was cargo to be handled.

Figure 3.3.1

### Time Distribution and Performance Measures

<table>
<thead>
<tr>
<th>A. Total Hours = 168</th>
</tr>
</thead>
<tbody>
<tr>
<td>B. Crane Demand Hours (80)</td>
</tr>
<tr>
<td>D. Working Hours (78)</td>
</tr>
</tbody>
</table>

Maintenance Hours ———> Maintenance During Non-Demand Hours

Maintenance Hours ———> Maintenance During Demand Hours

### Recommended Formulas

- **Demand Availability**
  \[
  \left( \frac{D}{D + E} \right) 100 = \left( \frac{75}{75 + 5} \right) 100 = 93.8\%
  \]

- **Maintenance Efficiency**
  \[
  \left( \frac{D}{D + E + F} \right) 100 = \left( \frac{75}{75 + 5 + 16} \right) 100 = 78.1\%
  \]

- **Equipment Utilization**
  \[
  \left( \frac{D}{D + G} \right) 100 = \left( \frac{75}{75 + 72} \right) 100 = 51.0\%
  \]
IV. POLICY

While Strategy represents the "What" of what we want to be and accomplish, Policy deals with the "How". Policy defines the approaches and practices which the organization will follow to accomplish the strategy. Policy identifies the operating procedures which will be required and the concepts which are to be embodied in each.

This section of the paper discusses those major policy areas which have a significant impact on equipment management and maintenance.

4.0 Equipment and Fleet Management

The UWIST study observed that there were, at many ports, major deficiencies in the management of the ports fixed and mobile equipment. The complement of cargo handling equipment did not match the work load imposed by the actual cargo traffic. Equipment was frequently kept in service well beyond its economic life. Equipment procurement practices have created situations which cause major difficulties for maintenance. Therefore, in this section, we discuss the planning of the port equipment fleet, methods of making the equipment replacement decisions, and equipment procurement practices.

4.1 Fleet Planning

There are a number of fundamental problems relating to matching a port's equipment inventory with the nature and quantity of actual cargo available to pass through the port. Procurement of new cargo handling equipment requires months and even years. Actual procurement is often preceded by months of negotiating financing agreements and obtaining governmental approvals. In some cases time consuming civil works must be completed prior to operation of the cargo handling equipment. Therefore, it is necessary to anticipate the probable cargo traffic years in advance.

Since modern cargo handling has become capital intensive, the level of investment in equipment is very substantial. The specification, selection and procurement of equipment can have a major impact, either favorable or unfavorable, on maintenance and operation of ports and, therefore, on the level of service provided to shippers.

It follows, then, that the port needs a reliable and timely equipment plan. The equipment plan, a vital portion of the annual capital budgeting process, should be incorporated into the port's corporate financial plan.

The UWIST study found that there were seven principal areas of deficiency, which were frequently observed, in current equipment planning practices:

- Excessive government controls and interference delay and frustrate the planning function.
Information systems were inadequate. In most ports visited, there were inadequate records of present demand and utilization of equipment on which to base predictions of future equipment requirements.

Figure 4.1.1

- A systematic equipment replacement policy was lacking.
- Reluctance and delays in the disposal of exhausted or obsolete
assets were commonly observed.

- In some cases the equipment plan failed to determine appropriate equipment inventories.

- Although most ports prepare traffic forecasts up to five and ten years into the future, the predictions were often unreliable and insufficiently detailed for equipment planning needs, particularly in the unitized and conventional general cargo trades.

- The equipment planning process was often poorly managed.

Figure 4.1.1 displays a schematic drawing of a logical equipment planning process.

Traffic Forecasts. Traffic forecasts must be developed in sufficient detail to allow calculation of volumes to be handled by each type of equipment. See Figure 4.1.2 for an example which applies to a container terminal with a container freight station.

Figure 4.1.2

<table>
<thead>
<tr>
<th>QUAY TRANSFER MOVES</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>IMPORT FCL</td>
<td>64,125</td>
</tr>
<tr>
<td>IMPORT LCL</td>
<td>42,750</td>
</tr>
<tr>
<td>IMPORT EMPTY</td>
<td>5,625</td>
</tr>
<tr>
<td>EXPORT FCL</td>
<td>33,750</td>
</tr>
<tr>
<td>EXPORT LCL</td>
<td>50,625</td>
</tr>
<tr>
<td>EXPORT EMPTY</td>
<td>28,125</td>
</tr>
<tr>
<td>TRANSSHIPMENT</td>
<td>12,000</td>
</tr>
<tr>
<td>TOTAL QUAY TRANSFER MOVES</td>
<td>287,000</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>TO AND FROM CFS</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>IMPORT LCLs TO CFS</td>
<td>42,750</td>
</tr>
<tr>
<td>EMPTYs, CFS TO POOL</td>
<td>34,200</td>
</tr>
<tr>
<td>EXPORT LCLs, CFS TO CY</td>
<td>50,625</td>
</tr>
<tr>
<td>EMPTYs, POOL TO CFS</td>
<td>42,075</td>
</tr>
<tr>
<td>TOTAL TO AND FROM CFS</td>
<td>159,550</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>GATE COMPLEX MOVES</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>IMPORT FCLs LEAVING</td>
<td>64,125</td>
</tr>
<tr>
<td>IMPORT LCLs LEAVING</td>
<td>0</td>
</tr>
<tr>
<td>IMPORT EMPTYs LEAVING</td>
<td>5,625</td>
</tr>
<tr>
<td>EXPORT FCLs ENTERING</td>
<td>33,750</td>
</tr>
<tr>
<td>EXPORT LCLs ENTERING</td>
<td>0</td>
</tr>
<tr>
<td>EXPORT EMPTYs ENTERING</td>
<td>0</td>
</tr>
<tr>
<td>IMPORT FCLs REIRCULATING</td>
<td>44,888</td>
</tr>
<tr>
<td>EMPTYs REIRCULATING **</td>
<td>8,888</td>
</tr>
<tr>
<td>TOTAL THROUGH GATE</td>
<td>157,276</td>
</tr>
<tr>
<td>TOTAL MOVEMENTS PER YEAR</td>
<td>613,926</td>
</tr>
</tbody>
</table>

* IMPORT FCLs REIRCULATING INTO THE TERMINAL AS EMPTYs
** EMPTYs REIRCULATING FROM THE EMPTYs POOL TO SHIPPERS
Types of cargo which require different handling equipment or different handling sequences must be specified. Also, changes in the nature of cargo products or container sizes must be anticipated, where they influence the handling equipment required.

The traffic forecaster must take into account the port's basic strategy, the port's competitive attraction, or detractions, the local and regional interport competition, and the port's marketing and pricing policies within the economic setting of the country.

Good market intelligence is essential to making sound traffic forecasts. Market information should include trends in seaborne trade, changes in ship routing and scheduling, developments in ship design and cargo handling technology, and related national, regional and global economic data. Similarly, the market forecaster must understand the needs and developments of the hinterland areas served by the port, including other nations where appropriate. In the ports visited by the UWIST team, market intelligence research is hardly ever done. Where it was done it was done poorly. Lack of good market intelligence has resulted in severe equipment/cargo matching problems.

Setting of Operation Department Objective & Performance Targets. These are the same operations objectives discussed in Section 3.2.

Calculation of the Equipment Work Load. Calculation of the equipment work load requires an understanding of the port operating methods so that each type of equipment which will handle the cargo can be identified. It then requires a knowledge of the anticipated hourly production rates for each type of equipment, for each category of cargo and cargo movement. The product of the hourly production rates times the volume of cargo yields the total number of equipment hours which will be required. Hourly production rates may come directly from the operations objectives. If they are not available in sufficient detail, it will be necessary to rely on historical production rates or advice from manufacturers and other users of similar equipment in the case of new equipment.

It is necessary that the derivation of the hourly production rates is understood. The question of non-productive hours come into play. It is preferable that the operating hours used to develop historical production rates should only represent those hours during which the equipment was productively handling cargo. Excluded would be idle hours due to lunch break, transit to working area, standby, etc. These factors will be recognized in a subsequent step when the required equipment levels are calculated.

Determination of Required Equipment Inventory Levels. Conversion of required equipment operating hours into required fleet size requires consideration of a number of factors:

- Equipment operational data is required. This includes shift and daily operating schedules, equipment utilization, equipment availability, delays and other lost time. If care is not taken in assembling historical data and planning operational procedures and in applying
these data to calculate equipment requirements, it will be very likely that significantly wrong conclusions will be drawn.

Operating practices must be understood, and can often be changed to reduce the size of the equipment fleet required. Equipment allocation procedures are important. For instance, transfer of equipment between berths or terminals, as the work load shifts, can improve equipment utilization. Scheduling of intraport moves for off peak hours can also be of benefit. The plan must recognize the extent to which these practices are followed. The planning process can function as a catalyst to stimulate such improvements in operating practices.

Equipment fleets must not be sized to meet "average traffic demand levels." Since fully outfitted container ships may cost between $25,000,000 and $100,000,000, ship operators place a high premium on quick turnaround in port. If the ships regularly experience significant delays, waiting for a berth, the larger modern container ships will either avoid that port or charge higher freight tariffs for material passing through that port. Shippers will try to find alternate delivery routes or charge higher prices for their products. Therefore, an effective port must be able to service ships, trucks and trains as they arrive without subjecting them to significant waiting time.

Container ships, especially, spend relatively short periods of time in port. It is inherent, then, that there will be times when there is no ship at the berth and much of the cargo handling equipment is idle. When a ship is at the berth a rapid rate of unloading and loading is expected. Therefore, it is necessary to make allowances for this peaking factor when planning fleet sizes.

**UTILIZATION OF PRIME MOVERS AT AN LDC CONTAINER TERMINAL, 1987** (Possible Machine Hours = 8,688)

<table>
<thead>
<tr>
<th>Unit</th>
<th>'Requisition' Basis</th>
<th>Utilization 'Hour-Meter' Basis</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Hours</td>
<td>%</td>
</tr>
<tr>
<td>1</td>
<td>4,176</td>
<td>48</td>
</tr>
<tr>
<td>2</td>
<td>7,059</td>
<td>81</td>
</tr>
<tr>
<td>3</td>
<td>7,059</td>
<td>81</td>
</tr>
<tr>
<td>4</td>
<td>7,059</td>
<td>81</td>
</tr>
<tr>
<td>5</td>
<td>3,694</td>
<td>43</td>
</tr>
<tr>
<td>6</td>
<td>3,694</td>
<td>43</td>
</tr>
<tr>
<td>7</td>
<td>3,694</td>
<td>43</td>
</tr>
<tr>
<td>8</td>
<td>3,694</td>
<td>43</td>
</tr>
<tr>
<td>9</td>
<td>3,694</td>
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</tr>
<tr>
<td>10</td>
<td>4,176</td>
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<td>11</td>
<td>4,176</td>
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<tr>
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<td>81</td>
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<td>7,059</td>
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<td>22</td>
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</tr>
<tr>
<td>23</td>
<td>7,059</td>
<td>81</td>
</tr>
<tr>
<td>Total</td>
<td>117,175</td>
<td>--</td>
</tr>
<tr>
<td>Average</td>
<td>5,095</td>
<td>59</td>
</tr>
</tbody>
</table>
Figure 4.1.3 (a)

**CARGO HANDLING PEAK DEMAND PATTERN**

**HYPOTHETICAL PORT**

<table>
<thead>
<tr>
<th>RANGE OF REQUIRED CRANE OPERATING HOURS PER DAY</th>
<th>NO. OF DAYS</th>
<th>REQUIRED OPER. HOURS</th>
<th>CUMULATIVE DEMAND DAYS</th>
</tr>
</thead>
<tbody>
<tr>
<td>NONE</td>
<td>84</td>
<td>0.0</td>
<td>84</td>
</tr>
<tr>
<td>1-5</td>
<td>1</td>
<td>3.6</td>
<td>85</td>
</tr>
<tr>
<td>6-10</td>
<td>5</td>
<td>8.2</td>
<td>90</td>
</tr>
<tr>
<td>11-15</td>
<td>9</td>
<td>13.9</td>
<td>99</td>
</tr>
<tr>
<td>16-20</td>
<td>22</td>
<td>17.1</td>
<td>121</td>
</tr>
<tr>
<td>21-25</td>
<td>51</td>
<td>23.7</td>
<td>172</td>
</tr>
<tr>
<td>26-30</td>
<td>78</td>
<td>27.2</td>
<td>250</td>
</tr>
<tr>
<td>31-35</td>
<td>65</td>
<td>33.0</td>
<td>315</td>
</tr>
<tr>
<td>36-40</td>
<td>34</td>
<td>37.9</td>
<td>349</td>
</tr>
<tr>
<td>41-45</td>
<td>7</td>
<td>43.8</td>
<td>356</td>
</tr>
<tr>
<td>46-50</td>
<td>8</td>
<td>47.6</td>
<td>364</td>
</tr>
<tr>
<td>51-55</td>
<td>1</td>
<td>54.0</td>
<td>365</td>
</tr>
<tr>
<td><strong>TOTAL</strong></td>
<td>365</td>
<td>22.1</td>
<td>8051.2</td>
</tr>
</tbody>
</table>

Figure 4.1.3 (b)

**CONTAINER CRANE OPERATING HOUR DEMAND**

This point is illustrated in Figures 4.1.3 (a) and (b). Out of 365 days there were only slightly more than 140 days in which one crane,
and the associated yard handling equipment, would be sufficient to have served the traffic. During the remaining 225 days ships would have been obliged to wait in the queue if only one crane had been available. If, on the other hand, two cranes were available, capacity would have satisfied demand on more than 350 days of the year. Even though one crane would nearly satisfy the "average" demand, unreasonable queueing would have been imposed on the ships if only one crane had been available.

In this example we have assumed that the effective operating time of one crane is 20 hours per day. This, of course, may vary from port to port.

The port's overall objectives should specify the degree to which the port is willing to impose such delays on the shippers and carriers. These objectives will dictate the level of equipment which must be carried just to serve peak demand periods. Ports with high service level standards must be more generous in the sizing of equipment inventory.

Some ports utilize sophisticated mathematical techniques, such as probability theory, queuing theory and simulation models, to calculate the allowances for peak demand. Whether these complex methods or simpler data examination techniques are used, it is essential that the port consciously recognize the peaking factor in planning equipment inventory levels.

### EQUIPMENT UTILIZATION STATISTICS
**FOR A PORT, JANUARY-FEBRUARY 1988**

<table>
<thead>
<tr>
<th>Equipment Type</th>
<th>Inventory Level</th>
<th>Unis Supplied</th>
<th>Hours Worked</th>
<th>Utilization</th>
<th>Available Hours</th>
<th>Availability</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wharf cranes</td>
<td>29</td>
<td>25 (80%)</td>
<td>24,994</td>
<td>60%</td>
<td>38,842</td>
<td>93%</td>
</tr>
<tr>
<td>FLTs (3 t)</td>
<td>49</td>
<td>25 (51%)</td>
<td>40,090</td>
<td>45%</td>
<td>79,359</td>
<td>89%</td>
</tr>
<tr>
<td>FLTIs (5 t)</td>
<td>12</td>
<td>6 (50%)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>FLTIs (25 t)</td>
<td>1</td>
<td>1 (100%)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Electric FLTIs</td>
<td>10</td>
<td>6 (60%)</td>
<td></td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
</tr>
<tr>
<td>Mobile cranes</td>
<td>9</td>
<td>6 (66%)</td>
<td>5,705</td>
<td>44%</td>
<td>11,096</td>
<td>86%</td>
</tr>
</tbody>
</table>

One approach to meeting peak demands is through temporary hire of equipment from outside firms. If the equipment is readily available, it is simply a question of economics as to whether this practice should be followed. However, as cargo handling equipment becomes more specialized, the availability of such equipment for hire is less likely especially in less developed countries.
Reconciling Demand and Supply. Once the required equipment inventory levels have been completed, the existing fleet and the maintenance department objectives must be examined to determine the allowance required for equipment downtime. Equipment to be replaced is identified. This will establish the capacity of the existing fleet. This is compared with the required equipment inventory levels determined above. Alternatives which would reconcile this difference are evaluated.

Preparation of the Plan. Finally, the administrative and financial constraints must be recognized to finally determine the plan which specifies:

- The units of equipment which will be retained in service.
- The units which will be retired and disposed of.
- The units which will be acquired.

The plan should include the financial, market, and strategic justification for each recommended acquisition and disposal.

Developing the equipment plan should not be a one department function. It is necessary that all concerned departments, such as operations, maintenance, engineering, marketing and finance, should work to jointly prepare the plan. Each department has significant inputs and concerns which must be recognized.

We might add a word of caution. Ports which have received generous quantities of equipment through aid projects, may tend to take a relaxed attitude toward equipment planning on the assumption that more aid equipment will be forthcoming. This attitude results in uneconomic use of equipment and should be discouraged.

4.2 Decisions Regarding Equipment Replacement and Retirement

The decision to replace or retire equipment should be based on financial considerations rather than physical considerations. Equipment is often replaced while still in reasonable physical condition because the costs associated with operations, maintenance, performance and reliability are significantly higher than for new equipment. As such, this decision is best left to the port's financial department. However, much of the information data required for the decision must be provided by the operations and maintenance department. Therefore, it is important that these departments be aware of the factors affecting this decision and contribute to the decision. The following discussion examines both the data and the analysis used when deciding whether to retire or replace equipment.

A piece of equipment should be retired when the cost of keeping it is greater than the revenues it earns or the costs of providing the same service using other resources. A piece of equipment should be replaced when the cost of keeping the equipment is greater than the cost of disposing of it and procuring new equipment to perform the same function. In both cases, the
stream of expenditures for procuring, operating, maintaining and disposing of the equipment is analyzed. This analysis can be performed using either current prices, in which case the inflation is included, or constant prices, in which case it is excluded. In order to better understand these cost items, an example of a straddle carrier will be used in the following discussion.

4.2.1 Cost Components

There are four categories of expenditures. The first is the expense to procure the equipment whether as an initial purchase or as a replacement. This replacement cost is equal to the current market price for the equipment delivered to the port. It includes the costs for commissioning, training, and any spares provided with the equipment. This cost will increase from year to year but generally this increase will be similar to the rate of inflation. Therefore, when measured in constant prices, the replacement cost can be assumed to remain unchanged for the straddle carrier example, the replacement cost is assumed to be $275 thousand.

The second category of expenditures is the operating cost for the equipment. This cost will include both a fixed and a variable component. The fixed component is the annual cost for the salary and benefits of the permanent employees assigned to operate the equipment as well as other operating costs which do not change with the level of utilization of the equipment. The fixed cost usually increases with inflation but is unchanged when measured in constant prices.

The variable cost includes:

1. the cost for fuel and lubricants,
2. the overtime and bonuses for permanent employees,
3. the wages for casually employed labor assigned to operate the equipment, and
4. any other costs which increase with the number of hours that the equipment is operated.

The variable cost is usually computed as an average unit cost per hour of equipment operation. It increases more rapidly than inflation because of the gradual increase in the rate of fuel and lubricant consumption with age. For the straddle carrier example, the operating cost is assumed to have a fixed component of $20 thousand per year and a variable component of $10 per hour for a new unit. The latter increases at a rate 2½% faster than inflation.

The third category, the maintenance cost, also has fixed and variable components. The fixed component covers the maintenance that is performed on a fixed time schedule, for example, the annual or biannual maintenance check. This cost will increase with overall inflation but not necessarily with age. The variable component covers all repairs as well as the maintenance that is performed according to the number of hours of operation. This cost is computed as an average unit cost per hour of operation. It increases more rapidly than inflation due to the increasing frequency of repairs as the
equipment ages. For the straddle carrier example, the fixed maintenance cost is estimated to be $5,500 to cover the cost of the biannual inspection and repair. The variable cost is estimated to be $6.5 per hour for a new unit but is expected to increase at a rate 15% per year faster than inflation.

The fourth category is the resale value of the equipment if sold in the second-hand or scrap markets. The resale value declines with age and use. The resale value depends on the replacement cost, the effect of inflation is to increase the resale value by increasing the replacement cost. Given a relatively uniform level of utilization, the resale value, when measured in constant prices is expected to decline each year by a uniform percentage of the residual value. For the straddle carrier, the resale value is assumed to decrease at a rate of 10% of the residual value per year. The first 10% decrease occurs at the moment of purchase. This rate is exclusive of inflation.

The stream of expenditures for the sample straddle carrier over the first ten years is shown in Table 4.2.1 for a unit which was purchased at the beginning of the first year. These costs are in constant prices. The fixed costs for operations and maintenance are uniform throughout the period. The variable costs are computed assuming that the straddle carrier is used 3500 hours per year throughout its life. The total annual expenditure is shown in the right-most column of the Table. In order to determine the costs of using the equipment for different periods of time, the Present Values were computed using the discount rate of 10%. The discount factors and Present Value for each category of expenditure is shown in Table 4.2.2 together with the resale value which is presented as a revenue (negative expenditure).

The different categories of costs are totaled for each year and then summed to produce the Present Value of the equipment versus the years of ownership as shown in the second column from the left. This total includes the replacement cost which is expended at the beginning of the first year.

Obviously the Present Value will increase with the period of ownership. In order to make a comparison between alternative periods of ownership, it is necessary to interpret the results using a common period of time. In this case, the period is a year and value computed is referred to as the equivalent annual cost or EAC. The EAC is related to the Present Value, in the same way that the amount of loan is related to the annual payment for the interest and principal, assuming that the payment is constant throughout the life of the loan.

---

5 The Present Value is the sum of the costs for each year discounted to the base year. Discounting is a well established financial principle that involves dividing the expenditure in year \( t \) by an amount \((1+i)^t\) where \( i \) is the discount rate. This technique is used to determine the amount spent (or earned) in the current year which would be equivalent in value to an amount spent in a future year. Presumably a reward has to be offered to cause an individual to wait for one year to spend (or earn) a given amount of money. The discount rate is the amount of this reward divided by the amount of money to be spent. The simplest analogy is the interest rate a savings bank offers as a reward to its depositors for leaving their money in the bank.
### Table 4.2.1

**EXPENDITURE FOR A STRADDLE CARRIER OVER TEN YEARS**

<table>
<thead>
<tr>
<th>Year</th>
<th>Resale Present Value</th>
<th>Fixed Costs per year</th>
<th>Variable Costs (per hour of operation)</th>
<th>Total Variable Cost</th>
<th>Total Cost (per year)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Operating</td>
<td>Maintenance</td>
<td></td>
<td></td>
</tr>
<tr>
<td>0</td>
<td>247,500</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>222,750</td>
<td>20,000</td>
<td>5,500</td>
<td>10.0</td>
<td>6.5</td>
</tr>
<tr>
<td>2</td>
<td>200,475</td>
<td>20,000</td>
<td>5,500</td>
<td>10.3</td>
<td>7.0</td>
</tr>
<tr>
<td>3</td>
<td>180,428</td>
<td>20,000</td>
<td>5,500</td>
<td>10.5</td>
<td>7.5</td>
</tr>
<tr>
<td>4</td>
<td>162,385</td>
<td>20,000</td>
<td>5,500</td>
<td>10.8</td>
<td>8.1</td>
</tr>
<tr>
<td>5</td>
<td>146,146</td>
<td>20,000</td>
<td>5,500</td>
<td>11.0</td>
<td>8.7</td>
</tr>
<tr>
<td>6</td>
<td>131,532</td>
<td>20,000</td>
<td>5,500</td>
<td>11.3</td>
<td>9.3</td>
</tr>
<tr>
<td>7</td>
<td>118,378</td>
<td>20,000</td>
<td>5,500</td>
<td>11.6</td>
<td>10.0</td>
</tr>
<tr>
<td>8</td>
<td>106,541</td>
<td>20,000</td>
<td>5,500</td>
<td>11.9</td>
<td>10.8</td>
</tr>
<tr>
<td>9</td>
<td>95,887</td>
<td>20,000</td>
<td>5,500</td>
<td>12.2</td>
<td>11.6</td>
</tr>
<tr>
<td>10</td>
<td>86,298</td>
<td>20,000</td>
<td>5,500</td>
<td>12.5</td>
<td>12.5</td>
</tr>
</tbody>
</table>

### Table 4.2.2

**PRESENT VALUE OF EXPENDITURES FOR A STRADDLE CARRIER**

<table>
<thead>
<tr>
<th>Year</th>
<th>Discount Factor for 10%</th>
<th>Present Value of O&amp;M Costs</th>
<th>Present Value of Salvage</th>
<th>Present Value of Replacement Cost + Salvage Value + O&amp;M Cost</th>
<th>Equalized Annual Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0.909</td>
<td>$56,591</td>
<td>($191,250)</td>
<td>$140,341</td>
<td>$154,375</td>
</tr>
<tr>
<td>2</td>
<td>0.826</td>
<td>$111,725</td>
<td>($147,784)</td>
<td>$238,941</td>
<td>$137,767</td>
</tr>
<tr>
<td>3</td>
<td>0.751</td>
<td>$165,664</td>
<td>($114,197)</td>
<td>$326,467</td>
<td>$131,277</td>
</tr>
<tr>
<td>4</td>
<td>0.683</td>
<td>$218,650</td>
<td>($88,243)</td>
<td>$405,407</td>
<td>$127,894</td>
</tr>
<tr>
<td>5</td>
<td>0.621</td>
<td>$270,916</td>
<td>($68,188)</td>
<td>$477,728</td>
<td>$126,023</td>
</tr>
<tr>
<td>6</td>
<td>0.564</td>
<td>$322,678</td>
<td>($52,691)</td>
<td>$544,987</td>
<td>$125,133</td>
</tr>
<tr>
<td>7</td>
<td>0.513</td>
<td>$374,142</td>
<td>($40,715)</td>
<td>$608,426</td>
<td>$124,974</td>
</tr>
<tr>
<td>8</td>
<td>0.467</td>
<td>$425,504</td>
<td>($31,462)</td>
<td>$669,042</td>
<td>$125,408</td>
</tr>
<tr>
<td>9</td>
<td>0.424</td>
<td>$476,953</td>
<td>($24,311)</td>
<td>$727,641</td>
<td>$126,348</td>
</tr>
<tr>
<td>10</td>
<td>0.386</td>
<td>$528,667</td>
<td>($18,786)</td>
<td>$784,881</td>
<td>$127,736</td>
</tr>
</tbody>
</table>
loan. The EAC is computed from the Present Value using the capital recovery factor:

\[ CRF = \frac{i}{1 - \frac{1}{(1+i)^t}} \]

where \( i \) = the discount rate
\( t \) = the period of operation

This resulting annual costs for the different periods of ownership are shown in the right-most column of Table 4.2.2.

The analysis of the stream of expenditures - first by converting them to a Present Value and then converting the Present Value to an equivalent annual cost - has two immediate applications. The first is to determine the economic life of a piece of equipment. The second is to determine the appropriate time at which to replace equipment.

4.2.2 Economic Life

The economic life is the period of time that a new piece of equipment should be kept before being replaced with an identical unit in order to minimize the total cost. It is determined by computing the Present Values for procuring a piece of equipment and replacing it with identical units at fixed intervals. This interval is varied in order to determine the minimum Present Value.

The difficulty then becomes one of comparing Present Values which were calculated for different time periods. There are two ways to equalize the time periods. The first is to choose a period in which a replacement would occur in the final year for all replacement intervals. For example, a comparison between a four year and a three year replacement cycle must be made over a 12 year period, while a comparison between a four year and five year cycle must be made over a 20 year period. These comparisons can be continued until all possible pairs have been examined, however, the procedure is cumbersome. The second approach as suggested above is to compare the FAC for the different replacement cycles. This cost, when computed in constant terms, represents the annual cost which would be incurred over an indefinite period assuming that the piece of equipment is replaced at fixed intervals with a similar unit. The economic life is the replacement cycle which produces the lowest EAC and by implication the lowest Present Value.

When the equivalent annual cost for the straddle carrier example is graphed as shown in Figure 4.2.1, the economic life, 7 years, appears as the low point in the graph. For shorter cycles, the capital cost of a more frequent replacement results in a higher EAC. For longer cycles, the rising operating and maintenance costs increase the EAC by more than the savings from delaying investment in a new piece of equipment. The contribution of each of the four cost categories to this EAC is shown in Figure 4.2.2. It is important to note that the EAC does not change by more than 1% over the range
6 to 9 years. Since this variation is smaller than the accuracy of the estimates of operating and maintenance costs. The choice of an economic life can be chosen anywhere within this range.

4.2.3 Replacement

Another problem which can be analyzed by means of equivalent annual costs is the question of whether or not to replace a piece of equipment during the current budgetary cycle (or, more generally, when to replace a piece of equipment). Usually there are three options available. The first is to keep the equipment for another budgetary cycle. The second is to replace the equipment with a similar unit. The third is to replace it with equipment which has more capacity or capabilities. All three alternatives should be subjected to the same financial analysis.

The simplest analysis occurs when the choice is limited to the first two options. This problem is similar to the calculation of economic life but it concerns an existing piece of equipment. Therefore, the stream of expenditures for the existing equipment are computed beginning with the current year of operation. The Present Value for the existing piece of equipment is determined for different periods of ownership. These values are then added to the Present Value for a new piece of equipment purchased at the time the old equipment is disposed of and replaced at intervals equal to its economic life. In order to simplify this calculation, the Present Value for a cycle of replacements beginning in the end of year $t$ can be computed using the following formula:

$$\frac{EAC}{i(1+i)^t}$$

where $EAC$ = equivalent annual cost for replacement equipment

Calculations for the straddle carrier example are shown in Table 4.2.3. The EAC is approximately $125$ thousand, therefore the value of $EAC/i$ is $1.25$ million. The Present Value for replacements at seven year intervals is shown in the second column from the right as a function of the year of initial replacement. The operating and maintenance costs for the existing piece of equipment is shown in the left half of the table. These values differ from those shown in Table 4.2.1, because they are based on current expenditures. The values in the right-most column are the Present Values of the expenditures for the existing equipment used through year $t$ and the replacement units procured at the end of year $t$ and replaced every 7 years thereafter. The lowest value occurs if the equipment is replaced at the end of year 2. Thereafter, there is rapid rise in the cost of keeping the equipment as shown in Figure 4.2.3. The conclusion is that the equipment should not be replaced for the current budgetary cycle and an updated analysis should be performed in the following year when it is likely that the numbers will indicate that the equipment should be replaced.

One of the interesting features of these replacement calculations is that the timing of the replacement is not precise. This is due to the fact that the capital cost is considerably greater than the operating and
maintenance costs. This situation applies for most of the larger pieces of equipment used in a port. Another important feature is the assumption of smoothly increasing maintenance costs. In fact, the decision to replace a piece of equipment is usually made just before a major repair, such as an overhaul. The procedure for making the replacement decision remains the same, but the discreet expenditure for the major repair is included in the maintenance costs for the year in which it would take place. At the same time, the resale value should be adjusted to reflect the change in equipment value before and after the repair.

### Cargo Handling Equipment Age Profile for Several LDC's Ports

<table>
<thead>
<tr>
<th>Equipment Type</th>
<th>Depreciation Period (Yrs)</th>
<th>Numbers of Units by Age (Years)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>0-5</td>
<td>6-10</td>
</tr>
<tr>
<td>Forklifts</td>
<td>5</td>
<td>77</td>
</tr>
<tr>
<td>Tractors</td>
<td>5</td>
<td>0</td>
</tr>
<tr>
<td>Trailers</td>
<td>5</td>
<td>9</td>
</tr>
<tr>
<td>Mobile cranes</td>
<td>5</td>
<td>1</td>
</tr>
<tr>
<td>Portal cranes</td>
<td>20</td>
<td>0</td>
</tr>
</tbody>
</table>

Fig. 4.2.1

### Economic Life of Equipment

Using Equalized Annual Costs

![Graph of Economic Life of Equipment](image-url)
Fig. 4.2.2

EQUIVALENT ANNUAL COSTS
for the Individual Cost Components

- capital
- operating
- maintenance
- salvage
- Total

Fig. 4.2.3

YEAR FOR REPLACEMENT OF EXISTING EQUIPMENT
Fig. 4.2.4

YEAR FOR REPLACEMENT OF EXISTING EQUIPMENT

Table 4.2.3

STREAM OF COSTS FOR REPLACEMENT OF EXISTING EQUIPMENT

<table>
<thead>
<tr>
<th>Year</th>
<th>Fixed Costs</th>
<th>Unit Variable Costs</th>
<th>Total Operat &amp; Maint</th>
<th>Value of Salvage</th>
<th>Discounted Values</th>
<th>Present Value of Both for First Replacement in Year N</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Operat</td>
<td>Maint</td>
<td>Operat</td>
<td>Maint</td>
<td></td>
<td>O&amp;M</td>
</tr>
<tr>
<td>1</td>
<td>20,000</td>
<td>5,500</td>
<td>4.50</td>
<td>10.50</td>
<td>78,000</td>
<td>198,000</td>
</tr>
<tr>
<td>2</td>
<td>20,000</td>
<td>5,500</td>
<td>4.73</td>
<td>12.08</td>
<td>84,300</td>
<td>178,200</td>
</tr>
<tr>
<td>3</td>
<td>20,000</td>
<td>5,500</td>
<td>4.96</td>
<td>13.89</td>
<td>91,466</td>
<td>160,380</td>
</tr>
<tr>
<td>4</td>
<td>20,000</td>
<td>5,500</td>
<td>5.21</td>
<td>15.97</td>
<td>99,625</td>
<td>144,342</td>
</tr>
<tr>
<td>5</td>
<td>20,000</td>
<td>5,500</td>
<td>5.47</td>
<td>18.36</td>
<td>108,920</td>
<td>129,908</td>
</tr>
<tr>
<td>6</td>
<td>20,000</td>
<td>5,500</td>
<td>5.74</td>
<td>21.12</td>
<td>119,519</td>
<td>116,917</td>
</tr>
</tbody>
</table>
4.2.4 Equipment Selection

Another application of this analytical procedure is to evaluate the alternative pieces of equipment which have similar functions but different operating characteristics. If one piece of equipment has a higher replacement cost than another, but lower operating and maintenance costs, then the choice between the two can be made by comparing the equivalent annual costs of each over their respective economic lives. The same comparison can be used when one piece of equipment has a higher replacement cost and initial operating and maintenance cost, but deteriorates more slowly with age so that the resale value is higher and the operating and maintenance costs increase more slowly. In both cases, it is assumed that the pieces of equipment are replaced at the end of their economic life with the same unit. If, instead, the equipment is to be used for a fixed period and then disposed of, then the Present Value for that period can be used to select among alternatives.

4.2.5 Better Technology, Performance and Reliability

So far the replacement equipment has been assumed to be similar to the existing piece of equipment. The replacement of existing equipment with equipment which has better technology requires some increase in the scope of the analysis. The improved technology may offer lower operating and maintenance costs but may also require better trained operators and better trained and equipped mechanics. The additional costs for these personnel must be included in the operating and maintenance costs.

If the replacement equipment has a higher capacity than the existing unit, then the replacement decision can be reinterpreted in one of two ways; either the replacement units are used to replace a greater number of existing units or they are used to provide new capacity as well as replace existing capacity. In the former situation, one new unit can replace more than one existing unit or several new units can be used to replace an even greater number of existing units. In this situation, the costs are aggregated for the existing equipment and also for the replacement equipment. The procedure for determining when the replacement remains the same.

In the latter situation, the replacement equipment provides additional capacity. The decision is no longer limited to replacing existing equipment but also includes the question of whether additional capacity should be purchased. As such, this decision is treated as an investment problem and a comparison of costs and revenues is made to determine whether the investment is justified.

In both situations, it has been assumed that the replacement equipment is different from the existing equipment. However, the same considerations apply when the new equipment is the same as the existing equipment but offers increased reliability and therefore capacity. For example, a 6 year old straddle carrier may have an average availability of 50% and a handling rate only 75% of its rated capacity while a similar piece of equipment newly purchased has an average availability of 85% and a handling rate of 90% of capacity. The difference in performance must be factored into the analysis either by replaced a given number of units with a smaller number of units or
by taking into account the benefits from the additional capacity.6

4.2.6 Resale Value

The previous analysis is changed slightly when there is no resale value. This is common for fixed equipment and some special-purpose mobile equipment. The effect of a change in resale value can be understood if the resale value is subtracted from the replacement cost to determine the net capital requirement for procuring a replacement. The resale value effectively reduces the EAC for the replacement. Conversely, if there is no resale value, then the effective EAC is higher which increases the economic life of the equipment and extends the period until replacement is financially justified. The effect of a zero resale value or a more rapid decline in resale value are shown in Figure 4.2.4 for the straddle carrier example.

4.2.7 Retirement

For some equipment, the problem is not one of replacement but of retirement. The decision on whether or not to retire equipment depends on what will happen without the equipment. If the services provided by the equipment will not be continued after retirement, then the decision should be based on a comparison of the stream of costs and revenues which will result with and without retirement. If the equipment is to be replaced by leased equipment or another method of providing the same service, then the problem is one of replacement and the same analysis applies. The only change is that the costs for the lease or the other service are substituted for the cost of replacement equipment.

4.2.8 Capital Costs

There are several factors which increase the capital costs of new equipment and thereby alter both the economic life of new equipment and the timing of replacement of old equipment. The principal factors are high duties on imports and scarcity of foreign exchange. These increases not only the cost of new equipment but also the cost for the spare parts which increase the cost of maintenance for existing and new equipment. They also increase the resale value of the existing equipment which is linked to the replacement cost. An increase in capital costs reduces the importance of operating costs in the decision regarding replacement and tends to stretch out both the economic life and the period of ownership.

Another factor is inflation. So far the analysis has excluded consideration of inflation by using constant prices and a discount factor exclusive of inflation. This procedure assumes that the current prices of all cost components move in proportion to the general inflation index. Clearly in any given country, some of the cost components will increase faster than others.

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6 Where a fleet of equipment is sufficiently large and the units are replaced at regular intervals, this factor can be ignored. However, where a fleet of old equipment is being replaced in part or in total, then the performance should be considered in determining the number of replacement units.
inflation and others slower, but the overall effect does not invalidate the results obtained with constant prices. The one exception occurs in countries with relatively high levels of inflation where periodic sharp devaluations will change the cost of imported capital. Even where the devaluation is more or less continuous, there is a tendency for the relative costs of labor, energy, domestic capital goods and imported capital costs to change. In these situations, the effects of inflation should be included in the analysis. This can be done by projecting the rates of inflation for the different cost components and then performing the same analysis in current prices with the discount rate increased by the average rate of inflation.

Another effect of inflation is to cause the value of existing equipment as recorded in the accounts, i.e., the depreciated value, to considerably underestimate the true value of this equipment. However, in some instances, there is no secondhand market in which to establish the resale price. In order to estimate the resale value, the asset value in the accounts can be changed from the original price less depreciation to the replacement cost less depreciation.\[7\] Because of the importance of capital costs in the calculations of economic life and the timing of replacement and retirement, it is necessary to obtain reasonably accurate estimates of these values.

4.2.9 **Taxes**

The impact of taxes on the replacement decision and on the choice of economic life has been ignored because most ports do not pay taxes. However, with increasing participation of the private sector in the port business, it is useful to briefly discuss tax impacts. There are two ways in which taxes affect decisions regarding retirement and replacement. The first is the change in the cost structure for providing port services. The second is the depreciation of equipment. The change in the costs for maintenance and operation of the equipment result when equipment is replaced. If the new equipment has low operating and maintenance costs, then it effectively increases the port's income. This additional income will increase the port's tax payments. The result is that the after-tax savings in operating and maintenance costs are less than the before-tax savings. On the other hand, if the new equipment increases the operating and maintenance costs, then the port's income is reduced and the taxes are lowered. As a result the after-tax cost is less than the before-tax cost. This difference in tax payments should be included as a separate item in the stream of expenditures. It will be a negative amount if the expenditures are increased and a positive amount if the expenditures are decreased. For example, if the operating entity pays a fixed tax rate of 25% and the port is profitable, then a tax adjustment of \[\%\] of the change in operating and maintenance costs would be included in the

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stream of expenditures.

The effects of taxes on capital investment are more complex. The income on which the port's taxes are based is computed net of depreciation. When equipment is replaced, the level of depreciation increases. Since depreciation effectively reduces income and therefore tax payments, the increase in depreciation multiplied by the tax rate should be included in the stream of expenditures as a negative expenditure. When the equipment is sold, there will be a profit or loss depending on whether the resale value is greater or less than the original cost of the equipment less the accumulated depreciation. If a profit, the tax payment is increased whereas for a loss the tax payment is reduced. When deciding on equipment replacement, the one time change in taxes as a result of the sale should be included in the stream of expenditures together with the difference in annual taxes due to the change in depreciation. Savings in taxes through depreciation should be calculated for the existing equipment and the new equipment and the difference included in the stream of expenditures together with the profit/loss from sale of the used equipment.

4.2.10 Sources of Information

The basic information required when making a decisions on replacement and retirement of equipment is the projection of annual operating and maintenance costs as well as the replacement and resale values. The first two can be obtained by extrapolation from the port's accounting data, if detailed records are available. However, it is often the case, that information is not available for individual pieces of equipment and the experience of the operations and maintenance department are required. The specific data to be analyzed for each piece of equipment are the frequency and extent of maintenance performed, the rate of consumption of fuel and lubricants, the average availability and level of utilization. This data can be obtained from the performance reports for the individual pieces of equipment.

4.3 Procurement

The UWIST study frequently observed a variety of procurement practices which caused inappropriate fleet composition and impediments to sound equipment maintenance. Functions which require top management attention, in the equipment procurement area, are discussed in the following paragraphs.

Government Constraints. Some LDC governments require the port to purchase equipment through local dealers rather than direct from the manufacturer. In some cases this results in significantly higher costs to the port and diminished service. In other cases, there may be a very competent local dealer who offers the advantage of a nearby source of parts and service technicians. Ports should not be constrained to purchase from one source or another. They should have the option of purchasing from the best world wide source.

In more extreme cases, some ports are required to purchase from local manufacturer, if available, even when the quality of the equipment is far from satisfactory. This results in less desirable equipment being purchased, since the port is restricted from considering all sources.
Interministerial approvals, of individual purchases, often require as much as 4 months. This simply adds one more delay and increases the cost in the process of getting the appropriate equipment for the work load.

Ports are often required to purchase the lowest priced equipment, without regard to maintenance performance, fleet standardization, or service capability. There are all too many examples throughout the world of equipment fleets which do not perform their assigned work satisfactorily, simply because the vendor selection decision was made on the basis of the lowest initial purchase price without sufficient consideration to performance characteristics, reliability, and support services.

Port management should evaluate equipment on the basis of life cycle costs, which will demonstrate the financial impact of maintenance problems, poor durability, poor service from the manufacturer, excessive spare parts inventory, etc. If properly evaluated, with all costs being recognized, it is possible to buy the equipment which will have the lowest costs to purchase operate and maintain over its life.

There is a tendency to apply the same regulations to purchase of spare parts as are applied to the purchase of equipment. This is fundamentally inappropriate. The purchase of capital equipment is one which requires considerable scrutiny, for the decision has long lasting implications covering the life of the equipment. The options available to the port are often many. Purchase of spare parts, on the other hand, offers relatively few options and is vital to the cargo handling capability of the port. Spare parts purchases are repetitive, occurring virtually everyday. Therefore, procedures covering purchase of spare parts must be much more streamlined, with complete authority delegated to port management. It is important to appreciate that import duties and taxes often exceed 100% of the purchase price of the equipment and sometimes are as high as 250%.

Most importantly, the funds should be properly budgeted and readily available for purchase (including delivery costs) of spare parts. Placement of funds, in a hard currency bank account, earmarked for spare parts purchases is recommended.

Finally, excessive foreign exchange approvals and restrictions cause serious problems in equipment procurement and fleet management. This subject is discussed further in the next chapter.

Bilateral Aid. Aid programs often give the port no choice in the selection of equipment. In one case observed, a port had 8 different makes of forklift trucks, of the same capacity, with no common components between them. In another, temperate climate equipment was supplied to a tropical climate. While "free" equipment seems a free alternative, port management must assure themselves that the equipment is appropriate for their port. If not, the "free" equipment may cost more in the long run than purchase of the appropriate equipment in the first place. Therefore, careful attention must be given to specification of the equipment being received to ensure that it fits the needs of the fleet plan and the local working conditions.
The fundamental risk from bilateral aid projects is that the donor nation is often serving the interests of its own industry as well as the interests of the receiving port. When those interests are in conflict the port's interests invariably suffer.

**Procurement Policies.** Procurement is a port function which needs clearly defined policies and procedures to guide and direct the port staff. There are three reasons:

- There are sometimes a nearly unlimited number of options available to the port in supplying equipment needs. Therefore, port staff need direction to avoid spending undue time periods evaluating options and to avoid taking faulty courses of action.

- A number of departments are involved in the procurement process. Policies will help to ensure that all departments pull in the same direction.

- Personnel involved in procurement are subjected to substantial pressures from suppliers and other external forces. Clearly enunciated policies and procedures will help them resist inappropriate pressures.

It is a fact of life that the port's procurement policies must conform to policies established by the government's central planning unit and central tendering unit, The World Bank or other lending institution, as well as the needs of the port. Where the policies of the other agencies are contrary to the best interests of the port, relief should be requested by the port management and the agency should consider such request with the best interests of the port operation as the ultimate objective.

**Major areas requiring policy statements and procedures include:**

- When should the port buy "off the shelf" standard designs and when should it pursue custom designed equipment? Generally, off the shelf equipment has the advantages of being less expensive and possessing a proven track record in operation. Custom designed facilities and equipment are appropriate when off the shelf equipment will not satisfactorily perform the port's required work load. Policies should enunciate a number of tests which staff utilize to determine when the custom design course is to be followed. Such tests would include questions such as:

  - Will off-the-shelf equipment satisfy the required production rates?

  - Will it operate satisfactorily in the environment and conditions of our port? The person evaluating equipment must define those operating conditions in specific terms such as turning radius required, height of lift required, temperature conditions, etc.
- Does the equipment have a proven satisfactory operating track record in similar usage?

- Is the off the shelf equipment priced reasonably? If there are at least two competing off the shelf units, this will normally not be a problem.

- What quantity of spares should be purchased with the equipment?

- Should local suppliers be encouraged to manufacture spare parts? If so, under what conditions? For instance, "Only when they can obtain a license from the original manufacturer." or "Never when the equipment is still under warranty." etc.

- Policies should specify those situations in which competitive bidding is required.

- Policies should require that conditions relating to parts prices and availability, technical service, and training be negotiated, to the extent possible, at the time of purchase of equipment.

- Guidelines covering the application of standing orders and blanket supply contracts are required.

- Policies should specify the CIF point for purchase of equipment, or a set of guidelines which allow the purchaser to determine the appropriate CIF point.

- The port should state its policy regarding the entity which should normally have responsibility for commissioning and installation of new equipment.

- Methods and responsibility for determining bid lists and preparing bid documents should be spelled out.

- Policy should define the degree to which preference should be given to standardization of equipment.

The roles and responsibilities of each department, in the procurement process, should be very clearly defined. Internal procedures must be defined. In this regard, top management should take a close interest to ensure that internal procedures do not consume undue amounts of time, while still ensuring that each department is able to fulfill its responsibilities. That attention should not stop once the procedures have been defined. Management must also periodically examine the procurement practices to ensure that the procedures, as specified, are being followed.

Specifications and Bidding Documents. The UWIST study found that frequently equipment specifications were not adequately prepared. Effective procedures for writing specifications and bidding documents were not used. Port personnel often were not qualified to prepare the specifications, since this often requires specialized technical knowledge. Ports may find it
advantageous to utilize the services of a specialist consultant for preparation of specifications and bid documents and, especially, for evaluating the bids.

The World Bank has published "Sample Bidding Documents" in March of 1986. Appendix IV-2.1, included at the end of this section, sets out generic bidding document language relative to spare parts and technical support. Both of these documents could be used as guidelines in the preparation of specifications and other bidding documents.

Some ports tend to prepare "construction" specifications, e.g. weight, steel gauge, engine rpm's, etc. Functional specifications are usually more effective, because they can be related more directly to the needs of the port, whereas a machine which conforms to construction specifications may not perform the functions required by the port. In such a case there is no one to blame but port personnel.

Functional specifications require that the operating needs of the port be analyzed carefully and in detail. The types of functions which might appropriately be specified are illustrated by the following:

- Lifting capacity.
- Cycle speeds.
- Loaded travel speed.
- Lifting height.
- Turning radius.
- Dust combustion ignition protection.
- Minimum time allowed for PM service.
- Minimum time allowed for rope change out.

Specifications of this type should define the minimum standard which is acceptable to the port. They should include those performance features which are important and critical to the port's operation. Forget those which would be "nice" to have, but are not important.

The specifications should also define the responsibility which the vendor will have for installation and commissioning of the equipment including conditions of employment and taxation for expatriates brought into the country. In some cases, performance guarantees may be appropriate.

Since specification of equipment is so critical to the long range operation of the port and since it often requires unique and specialized knowledge, it is recommended that ports should utilize the services of experienced consultants for this task.
Specification and bid document preparation is one area in which the UWIST study found a lack of inter-departmental cooperation and cross consultation. Clearly, the maintenance department as well as the operations department should have ample opportunity to define their functional needs for inclusion in the specifications.

Bidding documents, of course, specify those commercial and legal terms which the port will require. Most ports successfully utilized one of several internationally accepted Conditions of Contract.

The bidding documents should make clear whether the vendor should include local taxes and duties in his bid.

Standardization. As equipment is acquired over the years from various sources, there is a tendency to accumulate a fleet that consists of a variety of makes and models. A non-standardized fleet creates numerous operating, maintenance, and financial problems. Operators must be trained and qualified on a number of different equipment types. This leads to lower productivity, accidents, and equipment damage.

Maintenance personnel must be trained and qualified in a great variety of preventive maintenance and repair procedures. This leads to higher maintenance costs and less effective maintenance, which in turn results in more equipment down time.

There is a growing trend in the industrial nations to reduce the number of suppliers, which allows the supplier and buying entities to form a closer relationship. The supplier is motivated to understand the buyer's needs and problems and to develop solutions, be they in equipment design or improved service. Equipment standardization makes possible the development of such relationships.

Finally, a nonstandardized fleet requires a larger inventory of spare parts. More warehouse space is required. Chances of being out of stock are increased. And most importantly, a substantial increase in investment in inventory is required. Figure 4.3.1 demonstrates that in one case the investment would be 42% less for a standardized fleet. Standardization of equipment does not guarantee 100% standardization of parts. As a manufacturer upgrades and modifies an equipment model, some parts change. The vast majority, however, will remain common.

The negative side of standardization is that such a policy may be interpreted, by the selected supplier, as an invitation to charge exorbitant prices and to provide substandard service. If a policy of standardization is followed, the supplier must understand that he will be expected to provide a superior level of service and the most competitive prices. This puts a burden on the port to define those standards of expectation and to monitor the supplier's performance. The implicit threat of dropping a supplier, if price and performance lag, must always be clear to the supplier.

Standardization of equipment may, in some cases, preclude the port from purchase of the most appropriate equipment. For instance, another supplier
may have developed a superior model. In such cases, the port must evaluate the advantages of continuing to purchase the standard equipment and compare that with the advantages of purchasing the superior competing equipment. If the superior competing equipment offers sufficient advantages the policy should allow the port to begin purchasing that equipment. Such decisions should be approved at the highest level of port management.

While 100% standardization will not be feasible in all cases, it is clear that ports should establish a policy of standardizing, to the extent that it is reasonably feasible. A compromise position is to establish a policy of two suppliers, where the equipment fleet is large enough.

If a port chooses a policy of standardization, it would not normally scrap the existing fleet and purchase an entirely new fleet. The more common approach is to standardize through normal attrition. As the old equipment reaches its retirement point, it is replaced with the standard equipment.

Standardization justification should be based on an evaluation of all the pertinent factors, utilizing life cycle costing.

Where equipment standardization is not practiced, it is possible to standardize on components. When procuring equipment, it is usually possible to specify the engine, transmission, etc. with the objective of utilizing common components across the fleet.

Technical Service, Parts, and Training. These topics should also be dealt with in the specification and bidding documents.

Bidders should be invited to identify the technical service which they can make available. They should specify the skill levels and experience of the technicians, the location of the technicians and the speed with which they can be dispatched, the language ability of the technicians, specialist engineers which might be supplied from the factory for particularly difficult technical problems.

Manufacturers should specify the technical services and spare parts which will be available locally and identify the entity which will supply them; i.e. a local dealer, agent, or branch of the manufacturer. They should demonstrate the extent to which they, the manufacturer, will ensure the availability and quality of the spares and service from local, regional or factory sources.

Regarding the question of pricing these technicians, some ports will require that the vendor include an amount for initial technical assistance in the equipment bid price. The problem with this approach is that the vendor is motivated to keep his bid price competitive and he will, therefore, minimize the technical assistance. A common problem experienced by ports is the short duration of technical assistance. A preferred approach is to request the vendor to quote independent unit prices, such as cost per man-hour, for this service. The port then can determine the amount of technical assistance it needs. The port is in control of its own destiny.
LDC ports often have difficulty in obtaining technical information about spare parts and components from the equipment manufacturer. Manufacturers often suspect that the LDC intends to have the part manufactured locally. The manufacturer has two concerns. One is the loss of anticipated revenue from sale of spare parts. The other is concern for the quality of locally manufactured parts and the effect that will have on the performance of the equipment and the consequential effect on the reputation of his equipment. Whatever the motivations and concerns, it is important that both the port and the manufacturer are open about their intentions and negotiate arrangements which are satisfactory to both parties. The best time, from the port's viewpoint, is at the time of purchasing equipment. Therefore, if the port will be requesting such information, from time to time, the right to do so should be specified in the bid documents.

If an LDC intends to arrange for local manufacture of parts, extreme care should be taken to ensure that satisfactory quality is produced. The safest arrangement is for the manufacturer to license a local producer, providing technical support to the local producer. A port should not be forced to purchase locally produced parts unless adequate quality can be assured.

Most equipment contains components, such as bearings, which are produced by a manufacturer who supplies them to the equipment manufacturer. If the port can purchase replacement parts from the original component producer, considerable cost savings can usually be achieved. It is usually difficult to obtain the names of the component producer and his part number from the equipment manufacturer. Therefore, it is recommended that this information be requested in the bid documents. That is the time when the port will have the best opportunity to get the information. It may be necessary to utilize consultants to specify the information requested.

It is common practice for LDC ports to purchase repair parts at the time of purchase of the equipment. A two year supply is commonly included in equipment purchase orders. It is certainly appropriate to arrange for supply of repair parts at the time of equipment purchase. There are two problems with this approach. First, it ties up more money and warehouse space than is really required. Second, many of the parts which are purchased are never required so the money has been spent on the wrong item.

A preferred approach is to appropriate funds for purchase of spare parts sufficient for a specified number of operating hours at the time of equipment purchase. For instance, if 10 straddle carriers are to be purchased for $625,000 each and it is the port's policy to appropriate funds for spare parts sufficient for 2,600 hours of operation, approximately 9% of the purchase cost, or $550,000 will be required. (Refer to Figure 5.0.1 in Chapter 5.0) Additional funds should be included for purchase of fluids and lubricants, if they must be imported.

Parts to be purchased immediately for the port's stock must be determined by maintenance and materials personnel who are experienced with equipment of that type and the parts which are likely to be required. The funds for future purchase of parts are placed into an international bank account (in the joint
EQUIPMENT STANDARDIZATION

EQUIPMENT STANDARDIZATION CAN HAVE A DRAMATIC IMPACT ON INVENTORY LEVELS, SINCE COMMON SPARES CAN BE STOCKED. THESE BENEFITS CAN BE ILLUSTRATED BY THE FOLLOWING RELATIONSHIPS:

1. USAGE (A) OF A SPARE PART IS DIRECTLY PROPORTIONAL TO THE NUMBER OF OPERATING UNITS (NU) THAT USE THE PART:
   \[ A = (K_1) (NU) \]
   WHERE \( K_1 \) IS A CONSTANT.

2. THE MINIMUM AVERAGE INVENTORY OF ANY PART IS EQUAL TO \( (EOQ/2) + \) SAFETY STOCK (SS).
   WHERE: \( EOQ = \sqrt{\frac{2 \times B \times A}{I}} \)
   AND \( EOQ = \) ECONOMIC ORDER QUANTITY
   \( B = \) COST OF PROCESSING AN ORDER
   \( A = \) USAGE IN DOLLARS (OR OTHER APPLICABLE CURRENCY)
   \( I = \) CARRYING COST OF INVENTORY EXPRESSED AS A DECIMAL

3. FROM THE ABOVE RELATIONSHIPS:
   \[ \sqrt{2} \times B \times \text{CONSTANT} = \frac{K_2}{1} \]
   THEREFORE, \( EOQ = K_0 \sqrt{A} \)
   FOR THE INVENTORY VALUE (INV) OF A PARTICULAR PART, THEREFORE:
   \[ INV = \frac{K_0}{2} \sqrt{A} + SS \]

4. FROM THE ABOVE EQUATION, AS THE NUMBER OF STANDARD UNITS (NU) INCREASES, THE INVENTORY INCREASES AS A FUNCTION OF ITS SQUARE ROOT.

THE FOLLOWING EXAMPLE ILLUSTRATES THE POINT:

<table>
<thead>
<tr>
<th>CASE A</th>
<th>CASE B</th>
<th>CASE B: IGNORING SAFETY STOCK</th>
</tr>
</thead>
<tbody>
<tr>
<td>20 STRADDLE CARRIERS MODEL X</td>
<td>60 STRADDLE CARRIERS MODEL X</td>
<td>INV = ( K_2 \sqrt{NU} = K_2 \sqrt{60} = K_2 \times 7.75 )</td>
</tr>
<tr>
<td>20 STRADDLE CARRIERS MODEL Y</td>
<td>20 STRADDLE CARRIERS MODEL Z</td>
<td>CASE B = ( 7.75 \times K_2 / 13.41 ) ( K_2 = 58% ) CASE A</td>
</tr>
<tr>
<td>20 STRADDLE CARRIERS MODEL Z</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

IN BOTH OF THE ABOVE CASES THERE ARE 60 STRADDLE CARRIERS, HOWEVER, IN CASE B THEY ARE ALL STANDARDIZED. IN CASE A THERE ARE 3 DIFFERENT MODELS, EACH USING DIFFERENT SPARE PARTS. THE INVENTORY OF SPARES REQUIRED TO SUPPORT THE EQUIPMENT IS SHOWN BELOW:

CASE A: IGNORING SAFETY STOCK,
\[ INV = K_2 \sqrt{NU} = K_2 \sqrt{20} = K_2 \sqrt{20} = K_2 \sqrt{20} \]
\[ = (K_2) (4.47) + (K_2) (4.47) + (K_2) (4.47) \]
\[ = (K_2) (13.41) \]

IN OTHER WORDS, THE INVENTORY REQUIRED TO SUPPORT 60 STRADDLE CARRIERS IS ONLY 58% OF THAT REQUIRED TO SUPPORT 60 STRADDLE CARRIERS COMPRISED OF 3 DIFFERENT SETS OF 20 EACH. IN REALITY, THE SAFETY STOCK REQUIREMENT WOULD ALSO BE REDUCED BY A LIKE PERCENTAGE SO THE ACTUAL REQUIRED INVENTORY IN CASE B WOULD BE EVEN SLIGHTLY LOWER THAN 58% OF THAT IN CASE A.
names of the port and the supplier) specifically for purchase of parts as they are needed to replenish stock. In this way part purchases match consumption patterns and undue delays in purchasing parts are avoided. A portion of the port's foreign exchange earnings should be added to the bank account, so that as the initial appropriation becomes depleted, there will be sufficient funds for continued purchase of spare parts.

Maintenance manuals, which are normally supplied by equipment vendors, are essential training and reference documents. They are critical to the functioning of the maintenance department. Port maintenance engineers commonly criticize the quality of manuals supplied. Specific criticisms include:

- Manuals are not well organized, often containing too much information about other equipment models.
- Operating and maintenance information is intermingled.
- Printing and copying is of poor quality. Treated paper can be used for workshop use.
- They are not well organized to be understood by persons who may be unused to reading technical documents. The use of good exploded diagrams is extremely valuable.
- Language translations are either inadequate or nonexistent.
- Specific local operating conditions and environment are not recognized.

There are two recommendations. Specify, in the bid documents, what is expected by way of maintenance and operating manuals. Secondly, recognize that the manual supplied will probably not be satisfactory for all of the port's training needs. It will, more than likely, be necessary for the port to extract and supplement information from the vendor manuals for preparation of training material. In this way the port can be in control of training, matching it to the unique needs and conditions of the port.

Equipment vendors can play an important part in training maintenance and operations personnel relative to newly purchased equipment. The bidding documents should invite the vendor to specify the training resources he has available and the unit prices he charges. This will allow the port to

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VALUES OF SPARE STOCKS IN A TYPICAL PORT (in $)

<table>
<thead>
<tr>
<th>Port</th>
<th>Stock Value</th>
<th>Annual Turnover</th>
<th>Maintenance Costs/Year</th>
<th>Spares/ M &amp; R Ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>2.7 M</td>
<td>6.3 M</td>
<td>15 M</td>
<td>18%</td>
</tr>
<tr>
<td>B</td>
<td>7.0 M</td>
<td>4.0 M</td>
<td>83 M</td>
<td>5%</td>
</tr>
<tr>
<td>C</td>
<td>N/A</td>
<td>2.2 M</td>
<td>7.5 M</td>
<td>29%</td>
</tr>
<tr>
<td>D</td>
<td>900,000</td>
<td>N/A</td>
<td>N/A</td>
<td></td>
</tr>
<tr>
<td>E</td>
<td>N/A</td>
<td>309,000</td>
<td>1.4 M</td>
<td>23%</td>
</tr>
<tr>
<td>F</td>
<td>N/A</td>
<td>500,000</td>
<td>2.5 M</td>
<td>20%</td>
</tr>
<tr>
<td>G</td>
<td>11 M</td>
<td>2.0 M</td>
<td>22.3 M</td>
<td>11%</td>
</tr>
<tr>
<td>H</td>
<td>5.3 M</td>
<td>890,000</td>
<td>2.36 M</td>
<td>38%</td>
</tr>
<tr>
<td>I</td>
<td>1.9 M</td>
<td>3.0 M</td>
<td>29.5 M</td>
<td>10%</td>
</tr>
<tr>
<td>J</td>
<td>N/A</td>
<td>295,000</td>
<td>600,000</td>
<td>50%</td>
</tr>
<tr>
<td>K</td>
<td>2.85 M</td>
<td>2.03 M</td>
<td>6.0 M</td>
<td>30%</td>
</tr>
</tbody>
</table>
incorporate the vendor resources into the ports training program as appropriate. The port pays for the service it utilizes.

Over the years when the equipment is in operation, large amounts of money will be spent on purchase of repair parts. Many of the parts can only be purchased from one source, the equipment supplier. To a lesser extent technical service is purchased also. The port normally has little or no control over the prices charged. Therefore, it is appropriate to obtain some measure of control over these prices at the time of equipment purchase. One possibility is to obtain a complete current parts price list and tie future changes in prices to appropriate published cost indices, or to identified changes in design or specification of an individual part. Each vendor may have alternative methods of providing price protection. The port should bargain hard on this point, at time of equipment purchase. That is when the port has some bargaining power.

**Bidders List.** Selection of bidders is often a difficult problem for LDC ports. Some are required to purchase from indigenous manufacturers, even though their equipment may perform poorly and be cost ineffective.

Other countries require purchase through local agents, rather than direct from the international manufacturer. The resultant problems include:

- The local agent cannot supply adequate technical support.
- The port is prohibited from going directly to the manufacturer for technical assistance.
- The purchase cost is higher.

There are three basic approaches to selection of suppliers for bid invitations:

- **International competitive Bidding.** In this approach any and all suppliers are invited to bid without formal pre-qualification. Most LDC's require completely open bidding. For much of the port equipment, many bidders will participate. Thirty bidders are not uncommon. If this policy is coupled with a requirement to purchase the cheapest, each purchase may result in a new untried model of equipment. Hence the bidding documents should incorporate objective evaluation criteria to select the lowest evaluated cost proposal instead of the lowest price. Also, strict post qualification criteria should be applied to ensure that the selected supplier and the equipment are proven and reliable.

- **Prequalification of bidders.** A general request is issued, to any and all potential bidders, to submit a statement of their qualifications for supply of the equipment or services being contemplated. After review of these submissions, a short list of the most qualified is selected. Firms on the short list are requested to submit bids. This process can be time consuming and, therefore, should be limited to supply of major engineering works.
For most cargo handling equipment prequalification submissions should not be required, since equipment used throughout the industry should be well known.

- **Selective Tendering.** For most routine equipment purchases of small value, a short list of bidders, unilaterally selected by the port, is recommended. This approach should be used when equipment and suppliers are well established in the industry, and their track records are well known.

The use of outside specialist consultants is often advisable when preparing the bidders list.

**Bid Evaluation.** Bid evaluation procedures in LDC ports were generally found to be lacking. Ranking criteria tended to be subjective and superficial. Bid evaluation procedures should include:

- Detailed review of equipment performance capabilities to ensure that they meet the specifications and the port's requirements.

- In-depth analysis of supplier performance relative to spare parts and technical service. Past performance with the port, with other ports, and other users of the equipment should be checked in detail.

- In-depth analysis of technical support aspects. Is the equipment easily maintained? Are components compatible with other equipment in the fleet?

Thorough evaluation of the financial impact. Comparison of the competing equipment units as to purchase price, delivery and assembly costs, life cycle costs, and performance capabilities should be carried out. Rigorous logic and analysis are necessary to objectively recognize the financial advantages or penalties of all of the cost and performance factors inherent in each of the competing machines. For this reason, the use of specialist consultants is recommended to assist port management in evaluating the competing bids.

The financial evaluation should be done on a discounted cashflow basis. Life cycle costs will often require a significant amount of research. If the port does not have detailed cost history for the equipment in question, it will be necessary to seek information from other ports and equipment users.

- If life cycle costing is not practical, a merit point system, similar to that demonstrated in the "Sample Bidding Documents - Procurement of Goods," published by the World Bank, may be used - particularly for small purchases.

**Receiving.** After equipment has been ordered it is necessary to ensure that the quality of the unit is acceptable. Engineering and maintenance personnel should inspect and test the unit thoroughly upon receipt. LDC ports often find it desirable to engage a recognized international inspection firm to
inspect equipment during design and fabrication and before it is shipped from the factory.

Skills. Personnel, engaged in procurement activities, often lack many of the skills required in the procurement cycle. Formal training is usually required. Salary levels for procurement personnel should be sufficiently high to attract and retain qualified personnel.
SPARE PARTS

Supplier must offer to supply any and all parts and components which may be required over the normal life of the equipment. Speed with which supplier can deliver parts to the port will be an important factor in bid evaluation.

It is the port's policy that, under normal conditions, equipment should not be down while waiting for parts. Bidders should govern their bid relative to spare part and component support, accordingly.

Bid evaluation will be based on life cycle costing. Therefore, estimates will be made of spare parts consumption over the life of the equipment and of the required investment in spare parts stock.

Spare Parts Bid Form.

Bidders are required to complete the Spare Parts Bid Form, which is attached hereto. Instructions for completion of the form follows:

- **Items to be included.** Parts and components which should be readily at hand are included in Category A. Include those items which will be replaced frequently, and on a continuing basis, such as gaskets, filters, belts, brake shoes, etc. and those items which will normally require replacement on an unpredictable basis and which are critical to continued operation of the equipment.

Parts and components, whose replacement, under normal conditions, can be readily planned sufficiently in advance to permit direct purchase of the item, without inflicting equipment down time, are included in Category B. These are items whose replacement is expected to be required over the equipment life, but which are not required to be readily at hand.

Exclude, from the bid form, those parts and components which, under normal circumstances, will not require replacement.

8 In many of the poorer countries this list should include everything required by the manufacturer's manual to be replaced or exchanged at the intervals recommended - including special lubricants and materials since these may well not be available "off-the-shelf" through local suppliers.

Also, items under Category A should be quoted to be supplied in batches of approximately six months supply (or some other period convenient to the port) to avoid the port having to stock large quantities of parts some of which may well deteriorate rapidly under tropical climate conditions.
The port intends to rebuild the __________ , __________ , and __________ components. Include all parts necessary for such rebuilds. For those components not listed above, do not include those parts which would be required only for rebuild of the component. If rebuilt components are available, so indicate in the description. List new and rebuilt components as separate items.

(1) **Item No.** This column contains a sequential number identification for each item.

(2) **Description.** Include the item description which should be used when purchasing the part.

(3) **Country of Origin.** Identify the country where the item is manufactured.

(4) **Equipment Manufacturer's Number.** Enter the item identification number which must be specified when purchasing the item from the equipment manufacturer.

(5) **Original Part Manufacturer's No. to be Supplied? Y/N.** The port wishes to have the option of purchasing parts from the original part manufacturer, if different from the equipment manufacturer. Bidder should indicate whether or not he will furnish the part identification number of the original part manufacturer. Enter Y for yes or N for no. If the part is manufactured by the equipment manufacturer, enter NA. Such part numbers will only be supplied by the successful bidder.

(6) **Item Unit of Measure.** Include the unit of measure by which the item is sold, e.g., each kilogram, meter, etc.

(7) **Quantity per Equipment Unit.** Identify the quantity of units which are incorporated into each equipment unit.

(8) **Work Unit of Measure.** Identify the unit of work in which the consumption interval (9) is expressed, e.g., hours, lifts, moves, etc.

(9) **Consumption Interval in Work Units.** Estimate, based on experience of equipment operated in similar conditions, the interval between part replacements. The interval is expressed in the same work units as defined in Column (8). A range of intervals may be shown if necessary. The purchaser may, at its option, examine the bidder’s records of the experience which led to the estimate. Intentional bias in this estimate will cause the bid to be disqualified.

(10) **Carried in Stock Yes/No.** If the item will normally be carried in the manufacturer’s or agent’s stock, indicate "Yes" in this column. If not, indicate "No".

(11) **Location of Stock.** If the answer in column (10) is yes, indicate the city in which the item will be stocked.
(12) **Available in Days After Order.** Indicate the number of days which will elapse, under normal circumstances, between the time of receipt of a purchase order and delivery of the part to purchaser.

(13) **Unit Priced FOB.** Specify the current price of the item delivered to purchaser at the FOB point. Specify the currency in which the price is shown.

(14) **FOB Point.** Indicate the geographic location at which the item will be delivered to purchaser.

(14a) **CIF Point Alternate.** Parts shipped from ______ shall be delivered CIF at ____________. Parts shipped locally shall be delivered FOB at ____________.

(15) **Price Adjustment Method.** Purchaser requests bidder to provide a guaranteed price for replacement parts for the life of the equipment. Bidder should describe the method or methods, in very specific terms, which will be used to adjust the Unit FOB price in future years. Preference will be given to adjustment formulas which utilize price indices which are in the public domain.

The Spare Parts Bid Form shall be submitted in hard copy as well as on a computer diskette in a specific format (to be specified by the port) that can be imported into the spreadsheet software being utilized by the port.

**CONSUMABLES**

Bidders shall identify fuel, lubricants, and other consumables and estimate the consumption. Consumption should be expressed per unit of equipment usage, such as operating hours, or unit of time, whichever is appropriate.

**SERVICE DOCUMENTATION**

The successful bidder will provide the following service documentation. Documentation will be bound and packaged in a manner that will permit easy reference and will protect the material from undue deterioration in conditions of normal workshop usage.

**Oil, Lubrication and Fuel Chart.**

The successful bidder shall identify oil and lubricant requirements, identifying the location on the equipment where the lubricant is applied, the quantity required in the original application and in subsequent applications, and the recommended lubricant specification. When recommending the lubricant specification, the climatic, environmental and other operating conditions, in which the equipment will operate, should be recognized. The interval between applications should also be identified, specifying the work or time units in which the interval is defined. For each lubricant specification, identify the approved product trade names used by each of the following lubricant
vendors: ____________.

**Parts Catalog.**

The successful bidder will supply _____ copies of a complete parts catalog. The catalog shall include the description, manufacturer’s identification number, and an indication of the component or section of the equipment on which the part is used. If available, parts catalog should also be supplied in ASCII format on diskette.

**Service Manual.**

The successful bidder will supply _____ copies of the service manual. The manual should be specific to the equipment being supplied. If the service manual includes references to models or components, which do not apply to the equipment being supplied, the references should be removed or, as a minimum, crossed out with an appropriate marking. The manuals should be expressed in a terminology which can be easily understood by competent repair technicians. Manuals shall be in the __________ language. If translations are required, they should be performed by personnel fully familiar with the appropriate technical terms and the __________ language as it is spoken and written in the region of the port. The manual should include ample sketches, drawings, etc. to supplement the verbal descriptions.

The service manual should include, but not be limited to the following:

- Identification of all (mechanical, structural, electrical, controls, etc.) preventive maintenance tasks. Task descriptions should indicate the location on the equipment and any procedural instructions necessary.
- A torque chart.
- Procedures for commonly recurring repair tasks.
- Electrical diagrams.
- Control system diagrams.
- Mechanical "exploded and cutaway" diagrams.
- Trouble shooting and diagnostic guides.
- Safe working procedures relating to safety hazards which are unique to the maintenance of the equipment.
- Tables of tolerances, specifications, and capacities.
- Identification of special tools required.
- As-built drawings (fixed equipment only).
- Special inspection procedures.

Manuals should be submitted, in draft form, for purchaser's review and approval. Final manual copies must be delivered to purchaser at least ____ weeks prior to placing the equipment in service.

TECHNICAL ASSISTANCE

Technical Services.

Purchaser may from time to time request technical service from the successful bidder. Bidder shall include, with his bid, a specification of the technical operational, engineering and maintenance skills which can be made available to purchaser, over the life of the equipment. The following information shall be included:

- Classifications of personnel which will be available.
- Minimum level of education, training and experience for each classification.
- Location where personnel are based.
- Language capabilities within each classification.
- The number of people in each classification which is currently available at each location.
- The prices which will be charged per day for each classification, and related commercial terms. Specify currency and conditions of payment. Indicate travel time required and class of travel by mode.
- Purchaser requests guaranteed prices over the life of the equipment. Define in detail the price adjustment formula or formulas which will be applied.

Training Services.

Purchaser may from time to time request training services from the successful bidder. Bidder shall submit, with his bid, a description of the operational and maintenance training resources which can be made available, as requested, to purchaser. Information shall include the following:

- A description of the training courses or modules which bidder has available. Learning objectives, training aids, instructional methods and instructional time shall be defined for each module.
- A listing of instructors which are currently available. For each, describe both the technical and instructional qualifications and experience. List the language capabilities of each.

- The prices which will be charged for the training services and related commercial terms. Include typical costs for accommodation and subsistence.
# RECOMMENDED SPARE PARTS BID FORM

**BIDDER**

**IFB NUMBER**

**DATE**

<table>
<thead>
<tr>
<th>ITEM NO.</th>
<th>DESCRIPTION</th>
<th>COUNTRY OF ORIGIN</th>
<th>EQUIPMENT MANUFACTURER'S NUMBER</th>
<th>ORIG PART MANUFACTURER'S NO. TO BE SUPPLIED? Y/N</th>
<th>ITEM UNIT OF MEASURE</th>
<th>QUANTITY PER EQUIP UNIT</th>
</tr>
</thead>
<tbody>
<tr>
<td>(1)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**CAT A PARTS**

**CAT B PARTS**
### RECOMMENDED SPARE PARTS BID FORM

**BIDDER**: 

**IFB NUMBER**: 

**DATE**: 

<table>
<thead>
<tr>
<th>ITEM NO.</th>
<th>WORK UNIT OF MEASURE</th>
<th>CONSUMPTION INTERVAL IN WORK UNITS</th>
<th>CARRIED IN STOCK YES/NO</th>
<th>LOCATION OF STOCK</th>
<th>AVAILABLE IN DAYS AFTER ORDER</th>
<th>UNIT PRICE FOB</th>
<th>FOB POINT</th>
<th>PRICE ADJUSTMENT METHOD</th>
</tr>
</thead>
<tbody>
<tr>
<td>(1)</td>
<td>(8)</td>
<td>(9)</td>
<td>(10)</td>
<td>(11)</td>
<td>(12)</td>
<td>(13)</td>
<td>(14)</td>
<td>(15)</td>
</tr>
</tbody>
</table>

**CAT A PARTS**

**CAT B PARTS**
5.0 FUNDING

The most common and important problem facing the maintenance departments in LDC ports is a shortage of foreign exchange for purchase of spare parts and equipment replacement. Most LDC ports surveyed are not allowed to keep even 3% of their revenues, even though they make large operating surpluses. Generally, the ports do not accumulate funded reserves for equipment replacement. In those cases where they do, the reserves are in local currency. Therefore, they must compete with other segments of the economy for the scarce foreign exchange.

Spare parts require a significant expenditure each year. Figure 5.0.1 demonstrates that annual maintenance costs, in U.S. dollars, for cargo handling equipment will range between 3% and 17% of the equipment replacement cost. Spare parts represent from 20% to 45% of the total maintenance costs. Most, if not all, of the spare parts cost will require foreign exchange. These allowances, based on the experience of a typical port in North America, are very dependent on the annual operating hours and, therefore, may vary, to some degree, from one port to another. LDC ports may have to adjust these allowances to reflect differences in operating hours, price levels, and maintenance experience.

The critical point illustrated by Figure 5.0.1 is that sufficient funds must be included in the annual maintenance budget, including the necessary foreign exchange portion. Port management, in approving and submitting budgets to higher authorities, must ensure annual funding for maintenance is included at roughly the levels illustrated in the figure, adjusted for local factors. In the absence of these funding levels, port equipment will deteriorate, cargo handling rates will decline and revenue earned by the port will be reduced.

Since ports are critical to the national economy and since they can generate foreign exchange, the port tariff structure normally generates foreign exchange and the port should be allowed to accumulate sufficient foreign exchange reserves for both spare parts and equipment replacement. Some ports, in fact, have modified their tariff structure so as to generate additional foreign exchange.

The port should be given autonomous control over a sufficient portion of the foreign exchange and local currency revenue which they generate. A few LDC governments have allowed the ports to earmark portions of their foreign exchange earnings for purchase of spare parts and equipment replacement. One port, for instance, is allowed to retain 50% of its foreign exchange earnings in a London, UK, account. The port has direct custody and authority over the revolving fund account from which it draws funds as required.

Port management and the government are faced with question of "How large should the revolving fund be?" There is no easy answer to this question. Clearly, the revolving fund should be based on:
### Figure 5.0.1

**ANNUAL MAINTENANCE COSTS AS PERCENT OF CAPITAL**

<table>
<thead>
<tr>
<th>Equipment Type</th>
<th>Annual (1) Operating Hours</th>
<th>Maintenance Cost (US$)</th>
<th>Capital Cost (US$) From $4,500,000 To $5,500,000</th>
<th>Maintenance as percent of Capital</th>
</tr>
</thead>
<tbody>
<tr>
<td>Container Cranes</td>
<td>2,300</td>
<td>$169,000</td>
<td>3 To 4 %</td>
<td></td>
</tr>
<tr>
<td>Gantry Crane:</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Rubber tired</td>
<td>2,000</td>
<td>$56,000</td>
<td>$950,000 To $1,000,000</td>
<td>6 % ---</td>
</tr>
<tr>
<td>Yard Tractor</td>
<td>1,100</td>
<td>$6,000</td>
<td>$43,000</td>
<td>14 % ---</td>
</tr>
<tr>
<td>Straddle Carrier</td>
<td>1,300</td>
<td>$71,000</td>
<td>$625,000</td>
<td>11 % ---</td>
</tr>
<tr>
<td>Forklift:</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>35,000 lb lift</td>
<td>2,000</td>
<td>$21,000</td>
<td>$125,000</td>
<td>17 % ---</td>
</tr>
<tr>
<td>97,000 lb (3)</td>
<td>2,000</td>
<td>$28,000</td>
<td>$275,000</td>
<td>10 % ---</td>
</tr>
</tbody>
</table>

Note: (1) 1989 Annual Costs, For Typical North American Port.  
(2) 1989 Quotation  
(3) Front Loader/Side Loader Types

**Distribution of Annual Maintenance Costs (1)**

<table>
<thead>
<tr>
<th>Equipment Type</th>
<th>Labor</th>
<th>Material</th>
</tr>
</thead>
<tbody>
<tr>
<td>Container Cranes</td>
<td>80.00%</td>
<td>20.00%</td>
</tr>
<tr>
<td>Gantry Crane: Rubber</td>
<td>75.00%</td>
<td>25.00%</td>
</tr>
<tr>
<td>Tired</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Yard Tractor</td>
<td>75.00%</td>
<td>25.00%</td>
</tr>
<tr>
<td>Straddle Carrier</td>
<td>60.00%</td>
<td>40.00%</td>
</tr>
<tr>
<td>Forklift:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>35,000 lb lift</td>
<td>60.00%</td>
<td>40.00%</td>
</tr>
<tr>
<td>97,000 lb (3)</td>
<td>55.00%</td>
<td>45.00%</td>
</tr>
</tbody>
</table>
Realistic estimates of revenue over extended periods of time.

Realistic estimates of spare parts requirements over extended periods of time typically converted to an annual requirement.

Realistic equipment replacement plans.

If these factors are known, it is possible to construct revenue retention ratios which will provide sufficient, but not excessive, revolving funds.

For purposes of calculating required fund allocations, equipment replacement should be segregated from spare parts. An allowance for spare parts can best be generated as an amount per equipment operating hour. This rate will be different for each type of equipment, of course. Refer to Figure 5.0.1. It should recognize age and condition of the equipment, historical parts usage for that type of equipment, and anticipated changes in spare part purchase prices. After these individual rates have been determined, they can be accumulated and converted into a percentage ratio of port revenue.

Similarly, equipment replacement allowances from depreciation accounts based on revalued assets should be built up from amounts required per operating hour. This will be based on estimated equipment lives (in hours), equipment condition, and revalued cost of equipment (including inflation forecasts). These hourly rates can also be converted into percentage ratios of port revenue. Refer to sections 13.3 Budgeting and 13.4 Foreign Exchange for additional information.

Since the allowances described above rely on a number of uncertain forecasts and estimates, it is essential that they be periodically reviewed and adjusted. Annual review, as part of the budgeting process, is normally sufficient.

There are many variations in techniques which can be used to fund the revolving accounts. The methods used are not so important, but it is essential that any port have a ready and sufficient supply of funds for these very essential expenditures. Given the importance of the maintenance function, it is better to err on the side of surplus allocations rather than shortages of funds. Surpluses can be used to reduce future allocations or may be passed on to the national treasury. Port management must put in place strict procedures to ensure adequate and accurate budgeting and particularly for disbursement against specific expenditures.
6.0 ORGANIZATION

6.1 Concepts

Port maintenance has traditionally suffered from organizational problems in many instances. Most frequently observed problems include lack of clear lines of responsibility, lack of delegation of authority, inability to get equipment released for maintenance and "desk bound" managers. Appropriate organizational structure and practices are essential to sound maintenance performance.

There are three basic organizational issues which can have a major bearing on the performance of the maintenance function.

- The first issue, to be discussed below, is the need for accountability and the underlying responsibility and authority.
- The second is the relationships between the operations and maintenance functions.
- The third involves the organization structure within the maintenance department itself.

Each of these issues bears on the other two. So while we discuss each of them individually, the reader should keep in mind that they are not isolated issues. After we have discussed each of these issues, we will present some organizational examples.

Accountability. It is a fact of human nature that people will likely conduct their activities more responsibly if they know that they will be held accountable for their actions. This concept is especially important in managing industrial and commercial enterprises. It has given rise to such motivational programs as "management by objectives" and "responsibility accounting". However, we do not favor incorporating these programs into the organization as ends in themselves. But we do encourage the use of the concepts.

In its barest essentials, what we wish to achieve is a situation where each employee knows what is expected. He also must account to his superior for the actual results of his efforts as compared to what was expected. This should be true of managers, supervisors, and craftsmen. This accountability should be a part of the normal everyday working procedures, and not just at those times which are set aside for special motivational meetings.

Accountability starts at the top. The Port Managing Director must be accountable, to the commission or board which governs the port, for all operations of the port, including maintenance. In turn, one of his subordinates should be accountable to him for maintenance of the port. That person has subordinates who are accountable for various portions of the maintenance activities.
As this paper develops, the reader will notice that many of the features of the recommended maintenance management approaches are designed to facilitate accountability. We believe, for instance, that each craftsman should know at the beginning of each shift, the work that he is expected to perform that day and at the end of each shift the supervisor should know what work was accomplished. This leads us to short interval scheduling and detailed tracking of work order progress, which are discussed in later sections of this paper.

A word of caution is appropriate here. To be effective as a motivator, the work expected must be reasonably attainable. If achievement of the "expected" is hopeless, in the employee’s mind, he will simply give up and not make an effort to achieve the expected results. He will work to some other standard.

We consider accountability to be the most important single factor to be considered when developing an organization structure. It must apply to managers and supervisors as well as at the craftsman level. Therefore, as the duties and responsibilities are being allocated to the various positions on the organization chart, it is essential that each position be defined to meet the following criteria:

- It must be possible to measure results. (e.g.; demand availability, maintenance efficiency, maintenance costs, etc.).

- Responsibility for results should not be divided between different departments in the organization. (e.g.; it would be a mistake to assign one department the responsibility to manage the performance of preventive maintenance [PM] and the responsibility to manage the performance of repairs on the same equipment to another.

- Responsibility and authority must be in balance. The person assigned the responsibility should have the authority to carry out the work. (e.g.; the person assigned the responsibility to perform maintenance on the cranes should have the authority to authorize work orders provided the work fits within the scope of an authorized budget.) This authority must be defined by senior port management.

An organization manual, which is demonstrated later in this paper, is a good method of establishing and communicating these organizational concepts as they are applied by the port.

Relationship with operations. All too often we find that the maintenance and operations departments appear to work at cross purposes. A typical scenario has the maintenance department requesting equipment be made available for PM, when the operations department cannot release it because it is needed for production purposes. It remains in service well beyond the PM schedule, until it finally fails in service. The maintenance department then has the equipment to repair, but since they were not prepared for the breakdown, they
are slow in returning the equipment to operations. This reinforces operation's reluctance to "give" the equipment to maintenance because they "never get it back".

A variation of this theme has the maintenance department receiving the equipment for preventive maintenance when scheduled, but then during the PM inspection detecting conditions requiring repair. They then proceed to accomplish the repairs prior to returning the equipment to operations. However, since they were not prepared for this repair, significant delays are experienced. The net result is that operations receives the equipment many hours, and even days later than expected. If the equipment can be safely and effectively operated, it should be returned to operations as originally scheduled and the repair scheduled for another day. Of course, if the equipment cannot be operated safely the repair must be made before the equipment is put back into service. In this case the operations department should be notified, as early as possible, of the delay and the estimated time when the machine can be returned to service. If the preventive maintenance program is effective, these delays will be the rare exception.

The importance of the operations department being committed to releasing equipment for maintenance when the maintenance department is planning to have it is the key issue. And, just as important, the maintenance department must be committed to the principle of returning the equipment to operations when promised.

At the same time both departments must recognize that circumstances change and it will sometimes be necessary for either department to modify their plans. Therefore, it is essential that both departments work in close cooperation so that such changes in the plan will have a minimum impact on the functions of the other department. Senior port management must ensure that both departments are fully committed to this philosophy and freely communicate with each other.

Achieving a condition of such harmonious relations cannot happen simply through senior management commanding it to happen. The expectations of the maintenance department must be reasonable, it must be possible for the operations department to release equipment at the time that the maintenance department is planning on it. The maintenance department must, in turn, have sufficient notice so that their work can be planned and scheduled prior to receiving the equipment. This, of course, cannot be achieved 100%, but it should be the organizational objective.

The key to success, in this regard, is joint planning, scheduling, and coordination between the two departments. Firstly, PM intervals should be agreed between both departments for each piece of equipment. Secondly, the two departments must jointly agree upon specific schedules. Since these schedules are always subject to change we normally suggest a series of planning and coordinating meetings. An annual plan is useful for scheduling major repair projects. A monthly planning meeting between both departments is useful so that the schedules of both departments are known to each other. However, since ships do not always arrive on schedule, an amount of flexibility is required. Joint weekly planning meetings are essential.
During this meeting, specific schedules day by day are agreed upon. Finally, brief daily meetings are required, wherein the operating and maintenance schedules for the following day are adjusted if necessary.

The need for close cooperation between the two departments is even more urgent in a few unique situations where maintenance responsibility is shared. Marine equipment usually relies on the vessel's crew for preventive maintenance and routine repairs. Major repairs are performed by the maintenance department. In such situations, one department or the other should have ultimate responsibility for maintenance of the craft. The other department provides a service, much as an independent contractor, to the responsible department. The servicing department must work to the satisfaction of the responsible department.

Senior management must recognize the operational and economic importance of the maintenance department. Too often the operations department is considered to be the "earners" while the maintenance department is considered to be a service group. The fact is that both departments are essential to the earning capability of a port. Therefore, the maintenance department should be given equal status with the operations department. The more successful ports have recognized their increasing dependence on equipment and mechanization by upgrading the status of maintenance, especially mechanical maintenance, within the port organization.

Placement of maintenance within the organization. The basic conflict between the operations and maintenance departments can be further mitigated by careful structuring of the reporting relationships within the organization. The question is, at which point do the two functions come together on the organization chart. The traditional organization approach demonstrated in Figure 6.1.1 will accentuate the problem. In this case any conflict will often be referred to the Port Director for resolution. There are at least three problems with this:

- The Port Director has more important matters to occupy his time than resolving such questions as "when a unit of equipment is to be scheduled down for maintenance".
- The Port Director should normally not be sufficiently informed on the day-to-day details of the operation and condition of equipment to make well informed decision of this type.
- It is more difficult for the two departments to respond to the overall port goals. They are more likely to serve their own departmental goals, rather than working together to achieve the overall port goals.
Figure 6.1.1

TRADITIONAL APPROACH

BOARD

PORT DIRECTOR

OPERATIONS MANAGER

MAINTENANCE & ENGINEERING MANAGER

ADMINISTRATION & FINANCE MANAGER

BUSINESS DEVELOPMENT MANAGER

PERSONNEL MANAGER

OPERATIONS SUPERVISOR

MOBILE EQUIPMENT SUPERVISOR

FIXED EQUIPMENT SUPERVISOR

OPERATIONS SUPERVISOR

Figure 6.1.2

RECOMMENDED APPROACH

BOARD

PORT DIRECTOR

DEPUTY PORT DIRECTOR OPERATIONS

ENGINEERING MANAGER

ADMINISTRATION & FINANCE MANAGER

BUSINESS DEVELOPMENT MANAGER

PERSONNEL MANAGER

OPERATIONS SUPERVISOR

OPERATIONS SUPERVISOR

MAINTENANCE MANAGER

SEE FIGURE 4.1.3
A recommended approach, and one which is being adopted by successful ports, positions the maintenance department, so that it reports directly to the operations director. In that way conflicts between the two departments can be more easily resolved to the direct benefit of the port operations. In this approach the maintenance department is independent from the engineering department, but receives technical support from the engineering department.

This recommended approach is illustrated in Figure 6.1.2. (There, of course, may be many variations on this basic theme to suit the needs of individual port situations. For instance, in small ports the Engineering Manager may be shared with other ports and spends only part of his time.

The following paragraphs elaborate on the applicable positions shown in Figures 6.1.2 and 6.1.3. The reader should not be concerned with the specific titles used for this illustration. There are a number of suitable titles for each of these positions and those used at the reader’s port may differ from those shown here. As an example, the Port Director position might be titled Managing Director, Director General, Executive Director, President, Chief Executive Officer, etc. depending on the local practice and on the scope of Corporate responsibilities.

In the recommended approach, the Operations Manager has been elevated to Deputy Port Director - Operations, reflecting the expanded responsibility of the position. It is not essential, of course, that the position be titled Deputy Port Director. If other conditions dictate, another appropriate title can be selected. But the position should have the full scope of responsibility indicated in the chart. In some organizations, it may also be appropriate for the Engineering Manager to report directly to the Deputy Port Director - Operations. The key to making this approach work is the attitude of the Deputy Port Director - Operations. He must accept responsibility for maintenance and give proper recognition to the importance of maintenance to the port's operation. Ports using this approach find that both maintenance and operations departments are more likely to work toward common port objectives.

Large ports are finding it advantageous to establish satellite workshops serving specific terminals or sections of the port. Advantages are:

- Maintenance work is performed nearer to the operational area reducing transit time and delays.
- Maintenance forces can specialize in a relatively few types of equipment.
- Cooperation and communications between operations and maintenance are improved.
- Maintenance reporting directly to a designated operations manager is facilitated.
Management of the port maintenance and engineering functions has traditionally placed more reliance on the civil discipline. With the increasing reliance on complex cargo handling equipment, the mechanical, electrical and instrument disciplines are becoming more important in the maintenance management staffing and structure.

**Organization of the Maintenance Department.**

Figure 6.1.3 displays a "generic" organization structure for a maintenance department. The specific circumstances of each port will influence the actual structure to be utilized. Therefore, this generic structure can only represent a guide which demonstrates organizational principles.

- **Craftsmen.** The craftsman positions will be segregated into different trades (mechanic, electrician, instrument repairman, etc.). These trade designations should be as broad as is practical. If the trade designations are narrowly defined, maintenance supervision will have limited flexibility in personnel work assignments and costs will be higher. It is recognized that trade designations will be influenced by local custom, government regulations, and union agreements. However, port management should strive for broad classifications. An example is the welding skill. It is desirable to have mechanics who can perform at least basic welding tasks. Another is mobile equipment mechanics who should perform work on the low voltage electrical systems.

![Figure 6.1.3](image-url)
Semiskilled Helpers. Most maintenance operations do not need unskilled helpers. However, in situations where skilled craftsmen are in short supply, helpers are often employed to maximize the efficiency of the skilled worker. If this is the case, these helper positions should be utilized as a training opportunity and staffed with apprentices.

Unskilled. Unskilled personnel are used for cleaning purposes.

Front Line Foreman. These people are responsible for assigning individual craftsmen to jobs and supervising their work. If at all possible, they should also have responsibility for maintenance of specified equipment and facilities, such as Container Cranes, Straddle Carriers, or Civil Facilities. This concept, which is sometimes referred to as "Area Responsibility" is desirable because it makes possible full accountability at all management levels. Larger ports will find the area responsibility approach easier to implement. Smaller ports may find it impossible to employ simply because of limited quantities of equipment and facilities.

The ratio of craftsmen to each front line foreman must be carefully established so that he is not overloaded on the one hand or under challenged on the other.

General Foreman. This is an intermediate line position reporting to the Maintenance Manager and having responsibility for a number of Front Line Foremen. Small ports will not have a need for this intermediate level of supervision. Larger ports will. Only if the positions reporting to the Maintenance Manager exceed an acceptable ratio should this position be considered. With this position in place a maintenance department will have three levels of line supervision. It would be a very unusual port maintenance department which would require more than three levels of management; maintenance manager, general foreman, and front line foreman. A fourth level should be avoided since each additional level tends to impede effective communication and performance within the department.

Electrical and electronic skills are very specialized, and it therefore is usually necessary to have supervision and craftsmen which specialize in these areas. Figure 6.1.3 shows one general electrical foreman who supervises electrical and electronics maintenance. This generic organization also has a front line foreman supervising these craftsmen. In smaller ports it will not be necessary to include the front line foreman. The general electrical foreman can supervise them directly.

Maintenance Planner. This position functions to assist the front line foremen and the general maintenance foremen. He plans work orders, ensuring that the necessary materials, tools and personnel are available before the work is scheduled. He maintains records
of the backlog of work for each unit of equipment and for each front line foreman. With this information he assists the front line foremen in preparing work schedules. He records, or supervises the recording of, work orders and completed work history. He prepares necessary reports for management. He prepares budgets and forecasts. An effective planner has an extensive knowledge of the maintenance work. Ideally, he will have had experience as a front line maintenance foreman. Since the role of the planner is to assist the front line foremen, he should report to the same person to whom the front line foremen report so that his top priority is to serve the front line foremen and the general foreman. Planners who are assigned to "central staff groups" usually fail because their priorities do not support the needs of the general foremen and the front line foremen.

- **Maintenance Engineer.** The organization should have at least one person who can apply professional knowledge and methods to solving technical maintenance problems. This position will analyze equipment failures, especially those which are recurring, determine their causes and devise solutions. He identifies recurring problems. He will normally prepare warranty claims. He will seek improved maintenance procedures and methods. He may be responsible for equipment modifications which will improve maintenance performance. He will assist in writing and reviewing specifications for new equipment. He maintains the facility documentation, including engineering drawings, vendor manuals, parts catalogs, etc.

In smaller ports this position may not exist as these functions may be performed by other personnel in the department. It may be necessary to use the services of an outside consultant to accomplish some of these functions. In either event each of the responsibilities should be assigned to someone.

In larger ports there may be additional technical staff to assist the maintenance engineer in carrying out his responsibilities.

- **Stores Supervisor.** Supply of parts and materials is critical to the maintenance department. Too frequently, supervision of stores and procurement are left to personnel who are not knowledgeable of and concerned with the activities of the maintenance department. A recent trend in port organization structure has the Stores Supervisor reporting to the Maintenance Manager. Stores and procurement personnel are being upgraded in terms of their compensation and status within the organization.

- **Training Coordinator.** Training is an essential function in LDC port maintenance departments. For that reason responsibility for training within the maintenance department should rest within the maintenance department. The Training Coordinator should be a person who is knowledgeable of maintenance practices and problems. Smaller ports will not need this specific position, as other
department personnel can perform the function on a part-time basis. A training department, if there is one, may provide support and assistance. (6.4)

- **Maintenance Manager.** He has ultimate responsibility for management of all personnel and equipment in the maintenance department and maintenance of all port equipment. He is accountable for maintenance costs, equipment demand availability and maintenance efficiency.

In developed countries' ports there is a trend toward a flatter organization structure in the maintenance departments. In many ports, two management levels in the maintenance department should be sufficient. In very large organizations three levels (Maintenance Manager, General Foremen, and Front Line) may be required. Excessive layers of management impede communications between management and the craftsmen, cause delays, and generally reduce motivation. In many LDC ports maintenance management is too far removed from the technicians, both organizationally and geographically. In that situation, managers lose touch with the realities of the work place.

### 6.2 Performance Based Criteria

One of the basic objectives that we expect from an organization is good performance. From a manager's perspective, there are two series of questions which must continually be answered:

- **How good is performance?** Can it be improved? Which areas present the greatest opportunity for improvement?

- **How can we achieve these improvements?** How do we get our employees (craftsmen, supervisors, and managers) to want to improve? How do we get our employees to want to do the best they can? In short, how do we motivate our personnel?

**How good is performance?** Under ideal conditions each manager or supervisor will know what performance he expects from each of the employees who report to him and he will know what performance is achieved by each. Performance can be judged either objectively or subjectively. Both methods are normally used to judge the performance of an employee. The objective method relies on measured results, whereas the subjective method relies on feelings, emotions and ambiguous perceptions. Performance ratings based on the subjective method, too often, do not accurately reflect the contribution of the individual. Therefore, it is preferred to use objective methods, which requires the measurement of results; both expected and actual.

Maintenance costs and performance are directly related to people and equipment performance. The keys to controlling performance are:

- **Establish and implement a plan through a maintenance management system.**
Identify and measure appropriate process and labor-related quantities and variables.

When the measured quantity or variable indicates a deviation from plan, identify the fundamental problem causing the deviation.

Establish the corrective action required.

Apply the corrective action.

Continue to measure the variables and quantities to determine whether the corrective action is working.

Feed results into future plans.

An approach, which is called Performance Based Control, simultaneously controls costs as well as production through control of the physical quantities and variables. Costs do not occur independently, they occur as a direct result of physical activities. Performance Based Control provides the answers to the questions which naturally follow from the general list above:

- How to appropriately identify the physical items and variables that must be measured?
- At what frequency should they be measured?
- What resource inputs are required to exercise control, and from where must the inputs come?
- At what organizational level should each problem be analyzed and corrective action executed?
- How to establish what the "real" problem is?
- What management methodology is required?

The variables to be controlled are those that directly affect the physical items comprising costs: they must be defined in small enough "packages" to allow an appropriate corrective action to be identified and applied. If the variable is too broad in scope, such as poor availability, the fundamental problem requiring corrective action is difficult to identify. However, if the variable is preventive maintenance compliance yesterday, the information is specific enough to identify the problem and to take appropriate corrective action if a deviation has occurred.

Therefore, statistical data, to be effective, must be organized in a hierarchy that corresponds to the organization. Summary indices, such as mechanical availability of the straddle carrier fleet, are designed to alert higher management to problems on an exception basis. The summary information must be built from more specific information: e.g., availability of each unit; downtime hours, both scheduled and unscheduled, each shift; reason for the downtime; etc.
The key to effective control is to identify specific independent variables, that, if properly controlled by an individual supervisor, will minimize costs and optimize performance. The relationship between summary indices and independent control variables is illustrated in Figure 6.2.1.

The summary data, or indices, will alert managers to zero in on these more specific variables when a deviation from plan occurs. While it may be acceptable to review summary indices once per week or month, critical independent variables must be assessed and necessary action taken many times per shift. These independent variables and indices are referred to as control points. Generally speaking the higher levels in the organization will focus on indices or "average" data while the lower levels will actually control the independent variables which determine the short range performance of the port.

In order to fit the responsibility for managing control points into the organization it is necessary to "stratify" the control points according to their characteristics. The stratification of control points is a concept that requires that they be grouped into one of four different categories, depending on the resource inputs required to control them, the opportunity potential and the type of action which affects the control. Figure 6.2.2 represents a summary structure that can be used to stratify control points.

Figure 6.2.1
Figure 6.2.2

<table>
<thead>
<tr>
<th>CONTROL POINT CHARACTERISTICS</th>
<th>FEEDBACK FREQUENCY</th>
<th>APPROPRIATE MANAGEMENT RESPONSE</th>
</tr>
</thead>
</table>
| A. - SMALL MANAGEMENT RESOURCE INPUT FOR DESIRED CONTROL.  
- RELATIVELY EASY TACTICAL DECISIONS ARE REQUIRED TO MAINTAIN CONTROL. | HIGH FREQUENCY MEASUREMENT | FIRST LINE MANAGEMENT CONTROL THROUGH A SYSTEM. |
| B. - MODERATE RESOURCE INPUT REQUIRED.  
- SOME FORMAL STUDY REQUIRED.  
- SIGNIFICANT TACTICAL DECISIONS REQUIRED BY "MIDDLE MANAGEMENT". | MEDIUM FREQUENCY MEASUREMENT | PROJECT APPROACH BY MIDDLE MANAGEMENT. |
| C. - HIGH RESOURCE INPUTS REQUIRED.  
- SIGNIFICANT ENGINEERING STUDY REQUIRED.  
- STRATEGIC DECISIONS NECESSARY BY SENIOR MANAGEMENT. | LOW FREQUENCY MEASUREMENT | STRATEGIC PLAN GUIDED BY SENIOR MANAGEMENT. |
| D. - ESSENTIALLY FIXED COSTS OR PRODUCTION FACTORS WHICH ARE UNCONTROLLABLE WITHIN NEAR TERM TIME FRAME. | LOW FREQUENCY | TOP MANAGEMENT. |

An example of a type A control point might be "Percentage of scheduled work completed in a shift". This is a variable which the shift supervisor should influence directly as the shift progresses.

A type B control point might be "Crane demand availability per month". This index can be controlled by the maintenance superintendent, often through study of problems or implementation of new systems.
A type C could be "Maintenance costs per container throughput" on a semiannual or annual basis. Many factors will affect this index, but a major factor is the equipment employed or container handling system utilized. In either case changes would be made only after significant engineering and operating studies and senior management planning.

**Performance Standards.** Port management should recognize that while it is important to know what actual performance is, it is just as important to know what it should be. This makes it possible to quantitatively assess actual performance of an organization and of individuals within the organization. Therefore, the necessary planning and technical expertise must be applied to establish these performance objectives. The expectations, or standards, for each performance measure will normally be established by the supervisor and subordinate involved. However, senior management must maintain control of this to ensure that the expectations are consistent with performance of well operated ports.

From the manager's point of view, monitoring actual performance versus expected performance points the way to improving the operation. It allows the manager to identify those areas which can and should be improved. In some cases the conclusion may be that expectations should be changed.

**Motivation.** When we say that a person is motivated, we mean that person has something which drives him to do something; he desires an end result sufficiently so that he will put the effort forth which is necessary to accomplish his objective. How does a manager get his personnel to have sufficient desire? A port's maintenance policy should explicitly specify the methods which will be relied upon to stimulate motivation.

The manager must be sure that it is possible for his subordinates to accomplish the objectives. Therefore, he must ensure that they have:

- The necessary tools and facilities.
- The necessary know-how and training.
- The necessary parts, supplies and materials.
- A clear understanding of what is expected.
- The necessary budget and funds (both local and foreign currencies).

In many LDC ports, employee attitudes, at all levels in the organization, were negative. This is a subject which should have top priority with senior management.

People may be motivated by a number of different factors. In fact motivation usually comes from a combination of factors working together. People do not all respond to the same stimulus. What instills burning desire in one person will produce little motivation in another. Therefore, the motivational strategy should include a number of motivators and not rely on just one or two.
We must also recognize that differing social, cultural, and religious settings will have an important affect on the peoples' response to motivational stimuli. Therefore, each port must select its own motivational factors and must develop its own motivational strategy.

Some motivational factors which have been found to work well, most or all of which might be included in a port's maintenance strategy are as follows:

- **Continued employment.** This is perhaps the most important motivational factor. We tend to overlook this most obvious fact, that people will normally do whatever is necessary to keep their job. During the recession in the early 1980's many industrial workers in North America abandoned some long held "work rules" in the interest of returning their industries to viability and thereby protecting their jobs. When their jobs were threatened they were willing to work harder and more productively than they had been in the past. This is not a case of ruling by "fear". It is simply capitalizing on the fact that human beings will work hard and cooperate in finding solutions which will help to retain their jobs.

We recognize that many ports in developing nations, as well as some industrialized nations, have social legislation and or collective labor agreements which for all practical purposes prohibit terminating the employment of an employee who does not perform his job adequately. We can only recommend that senior officials work to amend such restraints. Such rules have a negative impact on performance and productivity and do not benefit society as a whole.

- **Inherent desire.** Most people take pride in their accomplishments. To tap this motivational factor it is simply necessary that the employee know what is expected of him. If a craftsman knows and understands his task schedule for the day he will proceed from task to task of his own volition. If he does not know, it is quite likely that he will "wait" until his supervisor tells him what to do next. Perhaps the most important motivational tool in maintenance is the daily schedule, which identifies the work which is scheduled for each craftsman.

- **Recognition by superiors.** Most of us will work more diligently if we know that someone else will know what we have done. That is why it is important for the maintenance strategy to include a provision that each person's superior should become aware of the performance of the subordinate. This recognition has both a negative and a positive implication. The employee will desire to avoid his superior being aware of his substandard performance. He will also enjoy knowing that his superior is aware of his good performance. This is the reason accountability is so important.
Recognition by peers. We also respond well when the people with whom we work, or people of the community, are aware of our own good performance. Therefore, we also recommend programs whereby personnel who achieve the objectives are given recognition through articles in the port magazine, notices on bulletin boards, awards at dinners, etc.

Compensation. Incentive systems which tie a person's pay check to his own performance have been known to be very effective. In these systems the employee's wage is adjusted or a bonus is calculated based on a quantitative measure of actual performance as compared to expectations. Before applying such systems, it is necessary to have confidence that the quantitative measures of performance do an adequate job of measuring progress toward objectives. If the performance measures run contrary to important objectives of the port, it is guaranteed that unwanted results will happen. In one port, for instance, equipment operators refused to move equipment from an incentive application to non-incentive work. Great care must be exercised in designing such systems.

It is also necessary that the system have sufficient flexibility. It is not unusual to find that the perceived objectives of port maintenance will change over a relatively short period of time, such as five years. Incentive compensation systems should not be allowed to be dictated by collective labor agreements. If that is likely to happen, the system should be avoided in the first place.

Compensation may also be tied to the skill capabilities of each craftsman. It can also be tied to additional training.

Additional training. A useful approach is to single out the good performers for further job related training. This has a double advantage. In addition to stimulating desire, it will give the training to those persons most likely to put it to good use.

Awards. A system of awards provides tangible benefits, beyond compensation, to those individuals who excel in their performance. Awards may take any form so long as they are a benefit to which the employee attaches value. They should not be confused with token awards which are useful for their "recognition by peers" value. Awards may be given to the employee, or to others who are close to the employee. For instance, an award program might provide educational assistance to members of an employee's family. This can have a double advantage of not only motivating the employee, but also serving a social need.

Job Enrichment. Quality circles, in which the maintenance craftsmen have the opportunity to participate in certain decisions, are successfully applied in several LDC ports. Costs are reduced and quality of service is improved.
Promotion. A system which promotes the good performers to positions of higher authority, responsibility and compensation is a sound motivational force. This does not mean that all employees who simply perform their jobs well should automatically be promoted. A person who is promoted should have all of the qualifications required of the higher job and be generally the best qualified of the candidates. When less qualified persons are promoted over the more qualified, a disincentive is created in the organization.

Sound Management. Perhaps the most important motivating factor is good management. People will enthusiastically follow a good leader.

6.3 Personnel Recruitment and Training

There is a trend, in successful ports, to staff maintenance management positions with personnel who are qualified in management as well as technical skills. This has implications not only for recruiting and promotion of managers, but dictates a need for greater training emphasis in this area.

Good management by itself will not make a good operation. It is also necessary to have qualified and willing people in the organization. Therefore, an important segment of a port's maintenance strategy deals with finding, training, and keeping an appropriate level of personnel; both management and craftsmen.

It is often assumed that if an adequate supply of qualified people is good, more qualified people is even better. Such is not the case. Overstaffing automatically produces lower productivity, and higher cost, simply because there are more people to do a fixed quantity of work.

However, overstaffing produces an even more serious problem. Too many people in an organization is actually a counterproductive condition and maintenance performance drops. Effective communication is inhibited and motivation drops. No one feels the same level of responsibility because there is presumed to be someone else who can perform the work. In effect, people are not challenged and, therefore, cumulative performance drops.

Recruiting & Retention.

Relatively few ports do an adequate job of forecasting staffing needs and planning recruiting activities. LDC port recruiting functions are often further confounded by bureaucratic cultural and governmental constraints. Union and nepotistic constraints are also often impeding factors. Recruiting of personnel has such long lasting impact on port operations and maintenance that senior management should ensure that these encumbrances do not interfere with an orderly and logical recruiting program.

Successful ports must ensure that their compensation, benefits, and working conditions are, in the aggregate, equal to or better than competing employers. They do not restrict their employment policies to match the
Recruiting for maintenance personnel, craftsmen, supervisors, and staff, should follow a methodical sequence. The basic steps which should be included in the program are:

- Define the requirements for each position; the skills which the incumbent must possess, the craft certifications which are required.
- Establish the quantities of people for each position which must be recruited.
- Identify the sources of people which will have these qualifications. If no sources will meet all of the qualifications, determine which will provide people who come closest to meeting the qualifications with the full understanding that the port will have to provide the required training.
- Document the skill capabilities and certifications which the port can expect to hire. From this define the minimum hiring standards for each position.
- Understand the competitive market for people meeting these standards. It is important that the port know, in detail, the compensation and benefits packages that other organizations pay. In the absence of government regulation of compensation and benefit levels, there is normally a substantial range between the highest and lowest paying employers.
- Establish compensation and benefits terms which the port must offer to attract and retain the required people. Bear in mind that a successful maintenance operation, in most societies, must attract people who have better capabilities and qualities than the average in the workforce. Therefore, it is necessary to compete with the higher paying organizations, not with the lowest paying. The port must be willing and able to pay what is required to get the "best". A useful approach combines compensation with training. As a craftsman accumulates more skills, through training and practice, his compensation rate increases. This has the double advantage in that it provides a more highly skilled maintenance work force and provides opportunity" for the employees. This will help to retain the better employees. Since a relatively small portion of the work force, perhaps 25%, will reach the top levels these people can be compensated very well in relation to the labor market without having a major impact on the port's cost structure. Figure 6.3.1 is an illustration of this approach.
Develop a good "sales presentation". Be certain that people in the labor market understand all of the advantages of working for the port.

Develop an advertising or other program which will put the port into contact with the desired candidates.

Applicants must be effectively screened to ensure that personnel hired will meet the minimum standards, or better. Screening normally will include:

- Testing.
- Interviews.
- Check work history and references.
- Verify education and results.
- Verify craft certifications.

Having recruited a work force, it is important to retain the people. Many of the same factors which help to recruit personnel will also function to keep them. The factors which help to maintain employee motivation, discussed in 6.2, are equally important to minimizing employee turnover. The primary ingredient leading to a contented work force is sound management and leadership. People will follow and remain loyal to leaders whom they respect. Good maintenance management is the key.
6.4 Training

Most LDC ports were found lacking in many aspects of their employee training programs. As port equipment has become more sophisticated and complex, the maintenance and operations personnel have not kept abreast of the technology change. Skills in electronics, diesel-electric, automation, and instrumentation are generally inadequate.

Operator training is important to maintenance. One European port has reported that a group of 12 new equipment operators were inadequately trained, resulting in a three fold increase in accidents and an increase of $450,000 in maintenance costs that year. At many ports there is evidence of premature scrapping of equipment due to poor training of maintenance staff and equipment operators.

When new plant and equipment have been installed, substandard maintenance often follows commissioning, indicating inadequate training relative to the new equipment. Some LDC ports display a need of full blown apprenticeship training, in-house. Materials staff often have received insufficient training.

Generally, where poor maintenance performance was observed, the cause was not lack of technical professional qualifications but lack of management skills. Most large commercial and industrial organizations in developed countries provide management training programs, covering a number of months, for new management recruits. Such programs were not found in most LDC ports. Management training clearly needs more attention.

Training programs, especially in LDC ports, must occupy a high priority in the scheme of operations. One very successful Asian port carries a training budget equal to 3.5% of total wages and salaries.

Since training is so important and generally found to be lacking, an audit of the training functions should be included as a routine part of technical assistance projects.

A training program for any port's maintenance department must be tailored to the specific needs of that port. Normally, the program will provide training for craftsmen, supervisors and staff.

Craft Training.

The approach to developing and implementing a trades training program must be based on job requirements and employee skills, and should consist of a logical systematic progression of learning experiences.

Steps required to accomplish this will include:

- Separate craft jobs into job classifications e.g., diesel mechanic, millwright, high-tension electrician, etc.
- Identify the significant tasks required of a craftsman within the context of each job classification.

- Based on the tasks required, determine the skill level required for each job classification.

Note: These steps should have been completed in preparation for a recruiting program.

- Assess the skill levels of presently assigned craftsmen (or anticipated craftsmen to be hired). This can be accomplished using a combination of several methods:
  * Supervisor interviews.
  * Interviews with the craftsmen themselves.
  * Selected testing.

The difference between the required skills and present skills will define the training objectives. In some cases it may be found that limited literacy and mathematical training is needed. Once the training objectives have been defined, development of training blocks and modules can begin.

Each training block is a course of training meant to satisfy a general training objective.

Training blocks are then subdivided into modules. A module is the fundamental building block of the training program. It consists of one to two hours of training designed to satisfy very specific objectives. Figure 6.4.1 is an example of a Plan of Instruction for one training module.

A learning path is developed for each job classification to graphically illustrate the entire training course. Learning paths are also useful to chart an employee's career training progression. Figure 6.4.2 displays a learning path example.

During the training program development a plan of instruction (POI) is prepared for the classroom training in each module. See again Figure 6.4.1. The POI will include:

- Specific learning objectives.
- Instructional methods to be used.
- Duration of each instructional method.

Most craft training programs should emphasize the "hands on methods" with classroom instruction limited to introduction, familiarization and the basic skill theories required. The usual ratio of classroom and on the job training (OJT) is 15% classroom and 85% on the job. This will provide a rapid rate of learning, higher retention and greater understanding of the tasks.
OJT also allows the employee to be productive while he is learning.

Plans of instruction should also be prepared for the on the job portion of training. This will identify the tasks for which the trainee should receive instruction and practice. The learning objectives should be stated in terms of the skills that the training is intended to develop.

The learning performance of each trainee should be evaluated at the end of each module and task. The trainee should repeat training on any module or task on which he cannot demonstrate satisfactory performance.

Training records should be maintained for each employee. The records will carefully track employee progress through the training program. The records will ensure that each employee has the required capability. They should also be used to ensure that employees do not receive redundant or unnecessary training. A skills matrix is maintained for each employee and represents his customized training record. As training modules and tasks are completed, progress is recorded on the matrix. These records are also used to prepare training schedules.

During the final stages of program development, a training load must be defined for each job classification to be trained. The training load will determine how many individuals in each craft must be in training at any given time. This is used to prepare an overall training schedule, which in turn will define the number of instructors required at any given time.

Instructors normally come from a number of different sources:

- The port's maintenance supervisors.
- The port's training department.
- Equipment vendors.
- Outside consultants.

Priority should be given to training in those skill areas that are most critical to the operation and in which the skill deficiencies are the greatest.

Maintenance Supervisor and Staff Training.

The development of supervisory and staff training is approached with the same basic methodology as for the craft training. Training programs usually include:

- Knowledge of equipment and facilities which are to be maintained.
- Supervisory skills.
- Port policy.
Planning and control.

Problem solving.

Figure 6.4.3 illustrates the typical sequence applied in development and implementation of a training program.

Training Responsibility.

Primary responsibility for training of maintenance department personnel should reside with the maintenance department head. If the port has an in-house training department the maintenance department may receive assistance and support from the training department. The maintenance department, however, must be the ones to specify the skills which are needed, evaluate training needs of each employee, make the employees available for training, and ensure that each employee receives the training he requires.

Training Resources.

A commonly used and valuable training resource is the equipment vendor. Utilization of that resource is encouraged. Caution, however, must be exercised. Deficiencies in vendor training, which have been observed, include:

- Language differences.
- Instructors not skilled in the art of instruction.
- Insufficient time allowed.
- Training not sufficiently focused on the learning needs of the trainees.

Ports should take control of their own destiny with regard to equipment related training. They should define the needs and specify the training to be accomplished. Then, to the extent feasible, vendor resources should be utilized, providing instructional material and instructors aimed at specific training requirements. Normally, vendor training will be supplemented with other resources. Outside consultants are often required to plan and organize the training relative to new equipment. This planning should be a normal part of new equipment acquisition.

Local technical institutes are also a potential source of maintenance training resources. Once again training from these sources should be tailored to fit the port's training needs, not simply programs which happen to already exist. In-house training departments often see these institutes as a threat, and the institutes, therefore, are often neglected as a potential resource. It should be the job of the in-house training department to find the most effective, and economical, resources and utilize them. The in-house department should not be allowed to develop a completely self sufficient instructional entity. Outside resources have too much specialized knowledge to be ignored. In-house training departments should be rewarded on the basis
of training results, not on the size of the staff they are able to accumulate.

Outside training and technical specialist firms also represent a potential resource. Finally, in-house line supervision represents a resource, and often an excellent one. They must, however, be given appropriate training in instruction.

Overseas Training.

Developing nation’s ports will find it convenient to train staff at vendor factory training schools and operating ports in developed countries. While this can be a useful method of training, it should be used with care. Unless the overseas training program is well defined and directly applicable to the individual’s training needs, it will be generally ineffective and expensive.

Figure 6.4.1

<table>
<thead>
<tr>
<th>MAINTENANCE TRAINING PLAN OF INSTRUCTIONS</th>
</tr>
</thead>
<tbody>
<tr>
<td>TRAINING UNIT: CONVEYOR MAINTENANCE</td>
</tr>
<tr>
<td>MODULE: PREVENTIVE MAINTENANCE INSPECTION</td>
</tr>
<tr>
<td>TRAINING AIDS: SLIDES, WORKBOOK</td>
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<tr>
<td>REFERENCE MATERIAL: CONVEYOR MAINTENANCE MANUAL - CHAPTER 5</td>
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<table>
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<tr>
<th>INSTRUCTIONAL ACTIVITY</th>
<th>OBJECTIVE</th>
<th>DURATION</th>
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<tr>
<td>LECTURE AND WORKBOOK PRACTICE</td>
<td>THE STUDENT SHOULD BE ABLE TO:</td>
<td>1 HOUR</td>
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<td></td>
<td>• IDENTIFY THE PRINCIPAL PARTS OF A CONVEYOR SYSTEM.</td>
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<td>• LIST THE CONDITIONS WHICH CAN CAUSE BELT MISALIGNMENT.</td>
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<td>• RECOGNIZE A SLUGGISH IDLER.</td>
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<td></td>
<td>• DESCRIBE THE PRINCIPAL PARTS OF A PILLOW BLOCK BEARING.</td>
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<td>• DESCRIBE THE CONSEQUENCES OF AN OVERHEATED MOTOR IF LEFT UNATTENDED.</td>
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<tr>
<td>FIELD VISIT</td>
<td>THE STUDENT SHOULD BE ABLE TO:</td>
<td>2 HOURS</td>
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<td></td>
<td>• LOCATE ALL OF THE CONVEYOR SYSTEMS.</td>
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<td>• LOCATE ALL COMPONENTS OF ONE CONVEYOR SYSTEM.</td>
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<td>• CONDUCT A PM INSPECTION OF ONE CONVEYOR SYSTEM.</td>
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ELECTRIC DRIVE TRAIN HAUL TRUCKS
ELECTRICAL ARTISAN LEARNING PATHS
Figure 6.4.3
7.0 MAINTENANCE: IN-HOUSE OR OUTSIDE CONTRACTOR - MAKING THE DECISION

Level of maintenance, as used here, refers to the scope or intensity of maintenance being performed by the port maintenance department. As an example, consider a diesel engine. One level of maintenance would be limited to preventive maintenance, i.e. lubrication, checking fluids, inspection, changing belts, hoses, filters, and making adjustments. A second level of intensity would include replacement of pumps, blowers, injectors, etc. A third level might consist of complete rebuild of the engine.

This section of the paper reviews various factors that will determine the levels of maintenance which a port can or should perform with their own forces and facilities. The primary question is, of course, "What are the available alternatives in getting the work performed?" Available alternatives usually include a nearby maintenance facility operated by a private contractor, an overseas maintenance facility, the equipment vendor's service center, or purchase of new components. Hereinafter, we will use the term "Outside Maintenance Contractor" (OMC) to refer to these alternatives collectively.

Reduction of the quality of equipment maintenance which is performed is not one of the alternatives. Whatever level of maintenance the equipment requires, that level must be performed. The question is simply "Who will do the work?"

The factors which normally affect this decision are the volume or frequency of the work in question, the need for specialized skills and equipment, and costs.

Each of these factors is discussed below. Even though they are discussed individually, in actual practice there is usually much interaction between them. Therefore, all factors must be considered before making the decision.

Please note that a similar question is discussed in section 12 of this paper; The Use of Outside Technical and Management Consultants. This section deals with performance of the work while 12 deals with know-how, both technical and managerial.

7.1 Types Of Maintenance

A review of the conceptual types of maintenance and repair activities is appropriate at this time.

- **PM.** Activities in this category are aimed at keeping equipment in good condition. Sub-categories include:

  * **Preventive.** This includes inspection, lubrication, cleaning, and adjustment of equipment, with the objective of avoiding wear or damage. These activities are normally performed at predetermined calendar intervals.
* Predictive. This concept recognizes that normal wear will occur. Action is taken before serious or catastrophic wear, damage, or other forms of deterioration occur. As the name implies, the actions are taken based on prediction of that moment in time which precedes serious deterioration. The predictions are based on the amount of usage (operating hours, lifts, moves, tons handled, etc.) or on the condition of the equipment. Condition of the equipment may be determined through visual inspections or through more sophisticated monitoring devices, such as vibration measurement, oil sampling and analysis, etc.

The activities include replacement of parts, replacement of components, or adjustments.

- Corrective. This includes repair and restoration of equipment which has become worn, damaged or deteriorated.

- Component rebuild and parts fabrication. These are functions which are normally provided by equipment manufacturers. It is these activities which are the more likely candidates for performance in-house.

- Failure analysis. When equipment suffers repetitive failures, it is appropriate to analyze the problem and determine the underlying causes. The answer may be in improved maintenance practices, improved operating practices, a warranty claim or in equipment design improvements. Close cooperation with the equipment manufacturer is required for this work to get his technical input. The manufacturer will normally perform the redesign work.

In addition to maintenance of the equipment, control of the working environment is important to the amount of maintenance which must be performed. Quay operating surfaces are particularly important. Uneven surfaces and potholes cause premature equipment failure. This is commonly a problem in LDC ports.

LDC ports perform most of the PM and corrective work, as defined above, in-house, relying on contractors for only the most specialized tasks.

There is a current trend, in the more successful ports, to adopting the component change out approach to maintenance. This has the advantage that the equipment down time is minimized.

7.2 Volume/Frequency

Work which is unique from the other port maintenance activities and which is performed infrequently should be considered for performance by an OMC. For instance a port which has an average of 12 diesel engines to be rebuilt each year will very likely utilize the services of an OMC for this work. A port, on the other hand, which requires 60 engine rebuilds per year
should give consideration to establishing a rebuild shop in-house.

Implicit in this decision making is the need for valid records of the volume of work which has been experienced, and more importantly valid forecasts of future work levels. An effective maintenance information system usually must have been in place.

It is also necessary that, when analyzing volume of work levels, the work is broken down into units which require identical facilities and similar know how. If the 60 engines to be rebuilt represented 10 different manufacturer models, an in-house rebuild facility would probably not be logical, since each model would require different know how. The work would not be very repetitive. Efficiency would be low and quality would likely be substandard. The work in such a case is better left to OMC's which specialize in those services.

7.3 Availability of Specialized Skills and Equipment

Certain maintenance work requires very specialized equipment and or training. Examples include nondestructive testing of crane structural members, rewinding electrical motors, computer repair, channel dredging, etc. Any port could, in theory, organize to perform this work in-house. But a port will usually find that there are OMC's which can perform this work more economically with dependable and satisfactory results.

When deciding to perform any type of work in-house, it is essential that the port understands exactly what will be required to do the work satisfactorily. The facilities, equipment and training which are required should be planned in detail. The port which underestimates the training and supervision requirements, for instance, will regret the decision to bring the work in-house. New ports will often contract more work out at the start of operations, bringing some of it in-house as they develop the in-house organization's ability to do the job.

On the other hand, the option of contracting the work out may not be so easily taken either. Care must be taken to ensure that the contractor is both equipped and qualified to do the work. The OMC's capability must be examined very carefully.

In essence this comes down to a question of "Which organization has the ability to do the work?" If, in fact, there is not an OMC which is capable of performing the work in a timely and effective manner, it may be necessary for the port to establish the ability to do the work in-house. In that event senior management must recognize that considerable resources will be required to:

- Specify the facilities, equipment, and tools which will be required.
- Plan the shop layout.
- Plan the work procedures and sequences.
o Plan work schedules.
o Plan the spare parts inventory, the in-process inventory, and component spares required.
o Estimate the local and foreign costs.
o Estimate manpower required.
o Train the personnel.

In most cases it is advisable for port management to utilize the services of outside consultants who are knowledgeable and experienced with the above subjects relative to the work to be performed.

A variation would be to assist an OMC to establish the capability through financial assistance, providing facilities to the OMC, or guarantee a certain level of business, etc. Once again the experienced consultant can assist in defining this arrangement.

7.4 Costs

Very often cost considerations will be the overriding factor in making the decision. The question to be asked by the port is "Which organization can do the work most economically for the port, provided they can do the work reliably, timely and to satisfactory standards?"

An OMC sometimes can produce certain maintenance work more economically because its labor costs are lower than the port's, he has surplus qualified labor, he performs a large volume of similar work for others, he is a vendor who will agree to favorable terms in the interest of making an equipment sale to the port, etc. When an OMC indicates that he can do the job at less costs, it is prudent for the port management to understand the reasons why his prices are lower. This will protect the port from an OMC who understates his costs in order to win the work and later asks for increased prices. In other words, the port should satisfy themselves that the savings are real and will be lasting.

In many developing countries an OMC provides services, to shipping lines such as, servicing and maintaining refrigerated containers, standard containers, chassis, tires, etc. This usually represents a substantial quantity of maintenance work. In fact the man-hours to perform this work may be as high as is required to maintain all of the terminal's cargo handling equipment. If such an OMC is providing a good efficient service to shippers, the port should consider the possibility of utilizing that OMC to perform maintenance on some of the port equipment. By virtue of the OMC's size he may be able to achieve economies of scale which can reduce the port's maintenance costs.

On the other hand, if there are no satisfactory OMC's available to perform this service for the shippers, the port may consider performing this work themselves. First, it is in the port's and the national interest to have
the shippers well served. Second, if the port performs this work their maintenance department can achieve economies of scale.

There is no easy answer. Each port must consider its own situation and make its decisions accordingly.

If the OMC is a domestic contractor and if foreign exchange is required for purchase of parts and materials, the port must give consideration to the manner in which the OMC will obtain the necessary foreign exchange. If the OMC is sufficiently substantial, he may be able to obtain the foreign exchange through his own resources. In most cases, however, this will not be the case and he will rely on the port for the foreign exchange. One approach which might be used requires the port to advance the necessary foreign exchange to the contractor. This advance should be based on well documented lists of materials to be imported. The port must satisfy themselves that the materials are, in fact, required for the work.

An alternative approach is to have the port supply the materials to the OMC who performs the work. This has the advantage that materials which are unused at the end of the job will revert to the port. It has the disadvantage that the OMC may be inconvenienced if the port is late in supplying the materials or if the material is unsuitable for the work. A financial claim from the OMC will almost certainly follow.

If the OMC is an overseas contractor, his entire fee will most likely require foreign exchange.

Where the supply of foreign exchange is very limited, it may be appropriate to consider performance of component rebuilds or fabrication of spare parts in-house. We must emphasize again, the importance of making certain that the in-house staff and equipment will be able to perform the work reliably. For this reason most ports do very little part fabrication work. The risks of off-standard work, or poor raw material, usually outweigh the benefits. Only parts which are used in large quantities, which are very simple to fabricate, and which do not require stringent specifications should be even considered for in-house manufacture.

In any event, when making the decision on the basis of costs, it is essential that the selected option will assure performance of the work to satisfactory standards. It is false economy to cut costs if the work will not get done properly.

7.5 Making the Evaluation

Making the decision to use an OMC for maintenance work or to perform it in-house requires the same logical evaluation process as is used for classical "make or buy" decisions in industry. Senior management should ensure that a thorough systematic analysis is made for each such decision. As a guide to establishing such a process, the following concepts are provided. Included is an evaluation form, Figure 7.5.1. Individual ports will very likely wish to develop their own format for presenting the evaluation. Each port may have unique factors which must be recognized.
SAMPLE EVALUATION FORM
LEVEL OF MAINTENANCE
IN-HOUSE VERSUS OUTSIDE MAINTENANCE CONTRACTOR

<table>
<thead>
<tr>
<th>I. MAJOR FACTORS INFLUENCING THE DECISION:</th>
</tr>
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<tbody>
<tr>
<td>WORK DEFINITION</td>
</tr>
<tr>
<td>FREQUENCY OR VOLUME OF USER PER YEAR</td>
</tr>
<tr>
<td>IN-HOUSE</td>
</tr>
<tr>
<td>LABOR SKILLS REQUIRED</td>
</tr>
<tr>
<td>AVAILABILITY OF LABOR</td>
</tr>
<tr>
<td>SPECIAL EQUIPMENT REQUIRED</td>
</tr>
<tr>
<td>QUALITY CONSIDERATIONS</td>
</tr>
<tr>
<td>OMC</td>
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</tbody>
</table>
### Sample Evaluation Form
**Level of Maintenance**
**In-House versus Outside Maintenance Contractor**

<table>
<thead>
<tr>
<th>II. Financial Evaluation</th>
<th>IN-HOUSE</th>
<th>OMG</th>
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<tbody>
<tr>
<td>ANNUAL COSTS</td>
<td></td>
<td></td>
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<tr>
<td>LABOR SHOP/CREW MANAGEMENT</td>
<td>COST</td>
<td></td>
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<tr>
<td>MATERIAL</td>
<td></td>
<td></td>
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<tr>
<td>EQUIPMENT CHARGES</td>
<td></td>
<td></td>
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<tr>
<td>CONTRACTOR CHARGES</td>
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<tr>
<td>TAXES &amp; MISC.</td>
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<td></td>
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<tr>
<td>TOTAL ANNUAL COST</td>
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<td></td>
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<tr>
<td>TOTAL EQUIV. LOCAL CURRENCY</td>
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</table>
### SAMPLE EVALUATION FORM

#### LEVEL OF MAINTENANCE

**IN-HOUSE VERSUS OUTSIDE MAINTENANCE CONTRACTOR**

<table>
<thead>
<tr>
<th>ONE TIME COSTS</th>
<th>IN-HOUSE</th>
<th>OMC</th>
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<tbody>
<tr>
<td></td>
<td>UNIT COST</td>
<td>QTY.</td>
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<tr>
<td>EQUIPMENT AND FACILITIES</td>
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<td>MOBILIZATION</td>
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<td>TRAINING AND START-UP</td>
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<tr>
<td>TOTAL ONE TIME COSTS</td>
<td></td>
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<tr>
<td>TOTAL EQUIV. LOCAL CURRENCY</td>
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</table>

#### III. CONCLUSIONS

**RETURN ON INVESTMENT**

**ANNUAL SAVINGS**

**RECOMMENDATION:**

**IN-HOUSE**

**LIFE OF INVESTMENT**

**OMC**

**LIFE OF INVESTMENT**

**REASONS FOR RECOMMENDATION:**

#### SIGNATURES AND APPROVALS

**ORIGINATOR**

**SPONSORING DEPT. HEAD**

**DIRECTOR OF OPERATIONS**

**PORT DIRECTOR**

**NAME:**

**DATE:**
The evaluation form compares the in-house option with the OMC option. If more than one OMC is being considered, the form can be expanded. Each caption in the evaluation form is discussed below:

- **Work definition.** The scope of the work which is being considered should be carefully specified. If engine rebuild is being considered, for instance, it is not enough to specify the work as engine rebuild. It is necessary to list all of the engine manufacturers and model numbers of each of the engines to be rebuilt. It is also essential to specify the scope of the rebuild. This information must be made available to the OMC as well as the in-house maintenance department to ensure that the comparison is between comparable scopes of work. If this is not done, the subsequent analysis will not be valid.

- **Frequency or volume per year.** The quantity of units of each work item (model number) which is expected to occur per year must be estimated. Normally, one will rely on past history as a guide. However, the estimate must recognize if the volume of work will be affected by conditions which will be different in the future than they were in the past, e.g. "There are now more equipment units in service", "The equipment is working more hours per year", "The equipment is now reaching the age that repair work will increase", or "The equipment is to be replaced with a consequent reduction of maintenance activity over the near term future". Past history should not be accepted blindly, since an error in the projected volume of work will distort the cost comparisons.

  Normally, volumes are projected to recur year after year. There may be occasions where the work being considered is a one time program. If so, this must be clearly stated and understood by the people performing the evaluation.

- **Labor skills required.** This box will specify the skills which are required of personnel performing the work. The work should be analyzed to understand any unique skills which are required. For instance, if stainless steel is to be welded, it is not sufficient to simply specify the need for welders, the stainless welding skill requirement must be specified.

  The quantities of labor required for the work must also be estimated. The best way to make such estimates is to use established standards for performing each element of the work. For instance, if we are considering rebuilding diesel engines, it is possible to obtain "flat rate" man-hour allowances which are used by factory rebuild contractors for pricing their work. These normally must be adjusted for the level of efficiency which is expected. It will often be necessary to utilize the services of an outside consultant to determine the adjustment which is appropriate.

- **Availability of labor.** This states whether the port has labor available who possess the necessary skills. If not, then the training required should be described.
The right hand side of the form states whether the OMC(s) has personnel with the skills.

- **Special equipment required.** This block specifies any special equipment, tools, or facilities which are required and indicates whether they are now available or must be acquired. This question is most important for the in-house option. But it is also useful to find out if the OMC will have to acquire equipment and confirm that he is planning to do so.

- **Quality considerations.** The purpose of this box is to indicate situations in which the quality of the work is particularly critical or in which quality is very difficult to achieve. In some cases this consideration will properly influence the decision.

- **Annual costs.** In this section of the report costs of doing the work are estimated for the volume anticipated. Costs are estimated for each option. We suggest that the various cost items be spelled out in sufficient detail to ensure that the estimate is complete, i.e. all cost factors have been considered.

  * **Labor.** For in-house labor the shop or labor crew which will do the work should be specified. In some cases more than one organizational group will be involved. The crafts which will be involved should also be specified. The cost per hour for each craft group is shown in the unit cost column. The estimated man-hours required for the defined amount of work is entered in the quantity column. The cost columns display the extension of unit cost times quantity.

    In some cases it will be necessary to expend port manpower resources in the OMC option. For instance, port personnel will be required to monitor the work of a local OMC. The cost of this task should be developed under the OMC option on the form.

  * **Material.** Similarly, the major items of parts and supplies which will be consumed in performance of the work should be itemized, priced and extended in this section of the form. Material may range from supplies consumed such as welding rod to parts and components which are used to replace worn items. It may be necessary to simply make a monetary allowance for miscellaneous materials which as a group are of relatively minor consequence. But every effort should be made to itemize the significant items.

    We should point out that the cost accounting system used by the port will have some bearing on which items of materiel are accounted for in this section of the form. Many shops will attach an allowance for consumption of minor supplies to the cost of the labor as a shop overhead allowance. If that is the case, such items will not be estimated in the material section of the form.
* **Equipment charges.** The section will include the cost of equipment which is charged by units of work, such as per hour. This may either be equipment which is operated by the port and charged out at an hourly rate or outside equipment which is rented or hired.

Once again if the port equipment is not charged out at an hourly rate, then it will be necessary to include the labor and material required to operate the equipment in the labor and materials sections of the form.

* **OMC charges.** This section will include any charges for outside purchased services. They should be itemized showing the unit costs and quantity for each service purchased.

* **Taxes and miscellaneous.** Any other costs which will be affected by the decision to be made should be itemized and included in this section.

We suggest that the incremental cost approach be used. For the in-house case only include those costs which will increase if the work is done in-house. Do not include costs which would be incurred in any event. To identify those costs which are impacted by the In-house vs OMC decision it is necessary to do a diligent job of answering the question "Exactly what will happen if we do the work in-house and exactly what will happen if we select the OMC option?"

If foreign exchange is an important consideration, local currency costs should be reported separately from costs requiring foreign exchange. They are totaled at the foot of the annual cost sheet. The two costs should also be displayed as a combined costs expressed in local currency.

* **One time costs.** This section shows the costs which will be incurred only once and which do not recur year after year. Normally, this represents the investment necessary to establish the in-house capability. But in some cases it will include mobilization or set up costs of the contractor.

* **Equipment and facilities.** This includes the cost of providing any new or additional facilities and equipment which will be required. Normally, these costs will appear in the in-house case. But it may, in some situations, be necessary for the port to provide equipment or facilities to the OMC. If so, the costs should be included in the OMC case.

* **Mobilization.** Often an OMC will require reimbursement for mobilizing his forces or setting up his facilities. Costs which the port must pay for this purpose are to be included here.

* **Training and start-up.** When a port begins to perform a new function which it has not performed in the past, certain costs will be incurred to train personnel in their new jobs and some inefficiencies are experienced in the first few weeks. Training
costs often include training equipment, outside specialists to prepare instructional material, instructors, and the time of personnel being trained.

Conclusions. This section of the form displays financial indicators which port management normally relies on and the recommended decision. We have suggested that both the annual savings and the investment be shown and identified as to which option they apply to.

In some situations there may be no investment required for either option, in which case annual savings would be the sole indicator of the financial benefit. Where both investment and savings are involved it is necessary to use an indicator which recognizes both. We recommend return on investment but other indicators such as "years to recover the investment" may be successfully used.

Return on investment is a commonly used indicator. Methods of applying it will be included in any financial manager's handbook. Return on investment is influenced by the number of years which will generate the savings. Therefore, the life of the investment must be indicated.

The department sponsoring the analysis will normally recommend one option or the other. The reasons for the recommendation should be clearly stated.

Finally, provision is made for the necessary approvals to be indicated. All ports should have a well defined procedure which specifies who in the organization has authority to approve such decisions. Normally, the approval level will be determined by the financial impact of the decision.

7.6 Selection and Control of the Outside Maintenance Contractor

If the decision is made to use an OMC, senior port management as well as maintenance management must recognize that it is still their responsibility to ensure that the work is done properly, timely, and economically. Therefore, care must be exercised in selecting and in managing the OMC. Following are some concepts which should be applied when contracting out maintenance work.

Before proceeding to select an OMC, the scope of the work must be carefully defined. There must be no confusion on the part of the OMC or port personnel as to what work is to be done. They must understand what the work is, where it is to be performed, the quantity of work, when it is to be done, and performance standards which will be expected. If either party has confusion about these matters, it is certain that difficulties will ensue later.

OMC selection. Normally, the contract award is made after a competitive process is followed, usually bidding. The first step is selection of a list of bidders. Care should be taken to be sure that all bidders have the capability to do the work, they have the necessary financial
strength, and they are reliable. There are a number of methods of preparing such a short list of bidders. Most commonly used are:

* Potential bidders are requested to submit their qualifications which are then reviewed and nonqualifiers rejected.

* References are solicited from other organizations which have used similar contracting organizations in the past.

* Recommended bid list from outside agencies such as the port's bankers, outside consultants, governmental agencies, etc.

Firms which do not meet the requirements should not be asked to bid, for it will be very awkward, if not impossible, to reject the low bidder for lack of capability. Further, the time and cost required to review each bid is significant. Therefore, selection of the bid list is very important.

Award of a contract normally recognizes the economics reflected in the bids. Weight should also be given to demonstrated ability to produce higher quality work and to the bidder who demonstrates a sound plan for carrying out the work.

- **Control.** Most OMC's will receive periodic work assignments from port personnel. Authorization of such assignments should be well documented. The quantity of work assigned and the OMC's commitment as to time of completion should be clearly established.

A member of the port's maintenance department should be assigned the responsibility to coordinate and manage all aspects of the OMC's contract. This designated representative should periodically observe the OMC's operations to ensure that appropriate practices and procedures are followed concerning the port's work assignments.

Work produced by the OMC should be checked for quality. The port's designated representative should be fully conversant with all aspects of the contract, but most especially with any warranty provisions. He is the person who should be responsible to identify warranty claims against the OMC.

To ensure motivation on the part of the OMC it is sometimes advisable to include a performance bonus or penalty provisions in the contract. Care should be taken when negotiating these clauses since motivation is a complex issue which may trigger the wrong actions by the OMC if the clauses are improperly constructed. It is advisable to utilize the services of a person experienced in bonus/penalty clauses when negotiating the contract.

- **Competition.** An OMC's on-going contract should periodically be put out for bids if possible. An OMC should not be allowed to become complacent. The best way to avoid this is to cause the OMC to know that he may lose the contract if his performance is not effective and economic.
7.7 The Contract

Terms and administration of a maintenance contract can be very complex. For that reason, a person familiar with maintenance contracts should draft the form of contract. If the selected OMC is very experienced with performing the type of work contemplated, it is probably appropriate to begin with a draft produced by the OMC. Specific contract terms may then be negotiated.

If the OMC does not have the necessary experience, it will fall to the port to develop the contract draft. Most ports will find it necessary to utilize the services of a consultant experienced in such matters to prepare the draft contract and to advise them during the negotiations.

There is great variation in possible contract terms. Contract terms must be tailored to fit the specific circumstances of each contract. Therefore, it is not possible to generalize on the contract terms which should be used. Nevertheless contracts can be categorized into three basic types:

- **Lump Sum.** In lump sum contracts, the contractor is paid a predetermined amount for completion of a given scope of work. From that sum the contractor must pay all of his direct expenses, overhead, taxes, and etc. and accumulate his profit. Progress payments may be scheduled for payment throughout the progress of the job.

  This method has the advantage that the Port knows in advance, the cost of the work. But the lump sum contract should only be used when the scope and quantity of work are sufficiently well defined to allow the contractor to estimate his costs with a reasonable degree of certainty. If the work is insufficiently defined, there is a substantial risk that the contractor will be financially unable to complete the work. If that is the case, the port may have to take alternative actions to have the work completed, at added costs and substantial delays.

  The other risk of insufficiently defined work may result in all bidding contractors over pricing their bids, simply to protect them from the unknown. In this event the port incurs excess costs.

- **Unit Price.** In this option, the work is defined in repetitive units, such as square feet of pavement placed, or cubic yards of channel dredged, lineal feet of piping replaced, square feet of siding painted, etc. The contractor is paid for the actual units of work completed at contracted unit rates. The contractor's profit is usually built into the unit rates, but in some cases his profit, or fee, may be paid as an additional lump sum. The method is advantageous when the nature of the work can be well defined, but there is some uncertainty about the quantity of work to be performed.

  This type of contract puts a requirement on the port to control and confirm the quantity of units of work performed, to avoid paying for more units than are required or supplied.
Time and Material. This is perhaps the most commonly employed type of contract for mechanical and electrical maintenance work. In this option, the contractor is paid for actual man-hours and equipment hours at contracted rates. In addition he is compensated for the actual materials used in the work either at cost or at agreed prices. In some cases the contractor charges a standard number of hours per job, sometimes referred to as the "flat rate", rather than the actual man-hours. This is common, for instance, in engine rebuilds. The contractor's profit is usually included in the unit rates and material prices, but it may be paid as a contracted sum in addition to the time and material charges.

This type of contract is appropriate when the nature of the work is well defined, but not when the extent is uncertain, as in mechanical repairs and rebuilds where the extent of parts replacements cannot be known until the work is underway.

In this type of contract an additional control responsibility falls to the port to be assured that excessive time is not spent and that unnecessary parts replacement does not happen.

Cost Plus. In this type of contract the port reimburses the contractor for his actual costs plus a fee (profit). It imposes major control burdens on the port, since all aspects of the contractor's costs must be examined and justified. Therefore, it is normally only used on major work, and seldom is utilized on maintenance contracts.

The advantage of this type of contract is that the contractor is protected from uncertainties and, if the contractor works efficiently, it can result in a lower cost to the port. However, this lower cost can be quickly offset by the costs of the necessary control organization. That is why it should only be considered for very large projects.

7.8 Case History

The principles discussed above were applied in an actual case which is summarized and attached as Appendix A.

APPENDIX A

ACTUAL RESULTS OF A STUDY TO DETERMINE THE ECONOMIC FEASIBILITY FOR ESTABLISHING AN IN-HOUSE COMPONENT REBUILD SHOP

A study was conducted which reviewed equipment component rebuild practices and appraised the economic feasibility of establishing an in-house component rebuild shop. The cost related findings of the study are summarized as Exhibit A. The study approach compared the present practice of sending all component rebuilds to outside vendors with the proposed practice of rebuilding most components in-house (approximately 90%) and sending the residual component rebuilds to outside vendors. Exhibit A is split into three sections to reflect these different practices:
1. Present Condition - Exclusive Use of Outside Vendors
2. Proposed Condition - In-house Rebuilds
3. Proposed Condition - Outside Rebuild of Selected Items

Labor costs, parts costs, other costs, sales tax and shipping costs are shown separately on Exhibit A for each of these three conditions.

The bottom line of Exhibit A shows the Gross Savings which would result from the proposed program to coalesce 2. - In-house Rebuilds; and, 3. - Outside Rebuild of Selected Items, and eliminate 1. - Exclusive Use of Outside Vendors. Gross Savings are found using:

\[
\text{Gross Savings} = 1. - (2. + 3.)
\]

Several factors contributed to the $352,000 cost savings. With respect to labor costs, in-house labor rates are considerably lower than outside vendor selling rates, since vendor selling rates add overhead and profit to base labor and payroll additives.

Outside vendors have a natural tendency to sell parts (with substantial mark-ups) and they must protect their warranties. Consequently, they tend to use more parts than would be used in an in-house rebuild operation. In the proposed case, a 20% savings accrues as the result of in-house procurement of parts. Also, sales tax and shipping costs are significantly higher in the present case where outside vendors are used.

As mentioned earlier, when analyzing the feasibility of an in-house rebuild facility, investment cost factors which offset the projected gross annual savings must be considered. In the referenced case, these cost factors and their respective dollar levels were:

- Land $85,000
- Shop buildings $3,430,000
- Support vehicles $75,000
- Shop equipment $1,078,200
- Spare parts inventory $1,184,000
- Training and startup $65,639

Exhibit B-1 thru B-5 illustrates floor plan sketches for the proposed component rebuild shop. Exhibit C summarizes the capital cost estimate for the shop building. The equipment list for required shop equipment is included as Exhibit D. Finally, a multi-year schedule of incremental spare parts investment is shown as Exhibit E.

The training and startup cost element includes consulting assistance, preparation of procedures manuals, and local payroll related costs associated with attendance by mechanics at a 10 day vendor's and a 14 day internal course.

Ultimately, gross annual savings generated from the change in rebuild practice, and the various offsetting cost factors associated with the proposed changes must be integrated and analyzed using a discounted cash flow format.
and an internal rate of return parameter. In this case, a 15.6% return on investment was anticipated.

Sensitivity analyses, which test various assumptions are appropriate.

The operation being studied had experienced an average 4,000 hour engine life. If, through improved maintenance and operating practices, the life of engines could be extended to 8,000 hours, the number of engines to be rebuilt each year would be reduced. Therefore, the potential savings would be reduced. In this case, it was calculated extending the engine life would reduce the return on investment from 15.6% to 14.0%. 
## COMPARISON OF COMPONENT REBUILD ALTERNATIVES

### EXCLUSIVE USE OF OUTSIDE VENDORS VERSUS COMBINED USE OF IN-HOUSE AND OUTSIDE REBUILD RESOURCES

<table>
<thead>
<tr>
<th>REBUILD METHOD</th>
<th>REBUILD TYPE</th>
<th>NUMBER OCCURRENCES</th>
<th>MAN-HOURS</th>
<th>LABOR COSTS</th>
<th>PARTS COSTS</th>
<th>OTHER COSTS</th>
<th>SALES</th>
<th>SHIPPING</th>
<th>TOTAL COST</th>
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MACHINE SHOP
ENGINE REBUILD SHOP
EXHIBIT B-5

SUSPENSION AND MISCELLANEOUS REBUILD SHOP

SHOP FLOOR PLAN

MISC REBUILD SHOP
## EXHIBIT SUMMARY

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<td><strong>BULK MATERIALS</strong></td>
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<td>Includes concrete, steel, architectural finishes, piping and electrical</td>
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<td><strong>INSTALLATION AND SUBCONTRACT (BUILDING SHELL)</strong></td>
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<td>Includes labor, construction equipment, tools and consumables, fuels and lubes, construction plants, temporary utilities, scaffolding, contractor's supervision, administration and mark-up</td>
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<td><strong>SUBTOTAL CONTRACTOR'S INSTALLED COST FOR THE BUILDING (28,400 SF)</strong></td>
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<td>(Installation labor included above)</td>
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<td><strong>COMMON DISTRIBUTABLES</strong></td>
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<td>(Includes sales tax, insurances, survey control, security and clean-up)</td>
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<td><strong>ENGINEERING, PROCUREMENT AND CONSTRUCTION MANAGEMENT</strong></td>
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<td>(Including engineers-constructor's fee)</td>
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**SUBTOTAL - MECHANICAL**

1028.60

| Electrical                        | 1        | Lot  | 46.60     |
| Instrumentation                   | 1        | Lot  | 3.00      |

**TOTAL PLANT EQUIPMENT**

1078.20
### COMPONENT REBUILD SHOP

**ESTIMATED INCREASED INVENTORY INVESTMENT PER YEAR**  
**ASSUMING A 10% INFLATION RATE**

**BASE CASE INVENTORY = $360,000**

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8.0 MAINTENANCE MANAGEMENT PROGRAMS

The term Maintenance Management System (MMS), as used in this paper, refers to a systematic method of managing the maintenance function. The term is not to be confused with Management Information System (MIS) which is a system to supply information to management. Certainly a major segment of an MMS is the supply of management information. Part of the MIS is a component of MMS. MMS goes beyond the providing of information. It also includes the utilization of the information in performing the management function. An MMS system is active whereas an MIS is passive. Implicit in this statement is the idea that unless management is using the MMS to make decisions and manage, the system is not functioning as an MMS, it is incomplete. Simply put, a computer system, in and of itself, will not solve the port's maintenance problems. An MMS will.

8.1 Objectives

The ultimate objectives of maintenance, and therefore the MMS, are to achieve high demand availability and maintenance efficiency coupled with low maintenance costs. The functional objectives of the MMS are to provide information in such a fashion as to facilitate the taking of appropriate action by each member of maintenance management and supervision and to ensure that each member is trained to take the appropriate action. In broad context the objectives of an MMS are to accomplish the following results:

- Establish the strategy for accomplishing appropriate maintenance of the facilities and equipment.

- Identify the independent physical variables, both process and labor related, which can be identified in the plan, and which will cause the plan to be accomplished if properly controlled. Variables include such items as man-hours to complete a repair, parts replaced, quality of each repair, preventive maintenance jobs completed versus jobs scheduled for individual items of equipment, appropriate scheduling of preventive maintenance jobs, etc. These variables should be items which individual people can control directly. The most basic application of this concept is the daily assignment schedule, which identifies the jobs that each individual craftsman is expected to complete during the shift.

- Identify indices which measure the effectiveness of the control of these variables. Examples are maintenance costs per equipment operating hour, equipment maintenance efficiency, equipment downtime hours each shift, etc.

- Provide for the measurement of these indices.

- When actual indices deviate from the plan, identify the fundamental problem causing the deviation. Identifying fundamental problems requires a great deal of skill and training on the part of supervisory and management personnel.
- Establish the corrective action required.
- Apply the corrective action.
- Continue to measure the indices to determine whether the corrective action is working.
- Feed the ultimate results into future plans.

The above steps represent a policy for effective performance and cost control. The MMS should provide these steps.

8.2 Computing Options

The use of computers, relative to an MMS, involves storing information, making calculations, retrieving information, and presenting information in useful formats. In years past the computing capability was the driving factor in selecting and implementing an MMS. Computing hardware was so expensive and software development so time consuming, that many decisions as to features which could be included in the system were literally dictated by the system designer. The maintenance manager was required to accept many compromises in the information which was made available and the timeliness in which he could get it. Development time for an MMS system of two years and more was not uncommon.

Developments in computer and software design in the last few years have overcome many of these difficulties. The maintenance manager can now have a system which will satisfy the needs of the maintenance department, without compromising the information which is required by other departments. Senior management should ensure that the computer system selected does satisfy the maintenance department and that the maintenance manager does not abdicate his responsibilities to the computer systems people. Quite likely the maintenance personnel will require some training as to the things that are possible through computers.

A port in virtually any country in the world has a seemingly infinite number of computing options. There are hundreds of different computer brands, models, and software combinations available today.

Computing options, however, fall into four basic categories:

- **Manual.** It is still possible to operate a satisfactory MMS without the use of a computer. All of the records and reports can be prepared by hand. However, computer based systems are generally preferred in today's world. The major advantage of a manual system is its simplicity. For this reason it is sometimes chosen, as an interim approach, in situations where the maintenance staff are very unfamiliar with MMS's and with computers. The need to learn both at the same time may result in such confusion that neither gets learned. In such cases a manual system should be used until all persons concerned are familiar with and comfortably
use the MMS. At that time computerization should be considered.

- **Personal Computers.** This may mean a single stand alone PC, but more likely a network of PC’s. PC’s have the advantage that the system can be programmed in commercial database software which is both flexible and relatively easy to learn. The net result is that the maintenance department can have their own engineers who are capable of maintaining and modifying the system. The system will thereby be responsive to the department’s needs and can be kept current as those needs change.

Additional advantages include the availability of preprogrammed systems which can be easily modified, which makes implementation in the matter of a few months possible. The cost of both the software and the computers is relatively small.

The one perceived disadvantage is that PC’s are not conducive to large fully integrated systems which handle everything from maintenance, to personnel, to payroll, to accounting, etc. PC’s can handle a system that integrates maintenance, inventory management, and purchasing. Beyond that, on-line system integration is not of any advantage to the user. If the other systems need information from the MMS, the data can be electronically transferred.

- **Mini Computers.** Mini computers have typically been, in the case of maintenance, dedicated to maintenance and materials management. Therefore, they have had the advantage that they can be controlled, to a degree, by the maintenance department. It is possible to buy preprogrammed systems, but they are generally less flexible than PC based systems. Experienced programmers are usually required to make modifications to the system, and these are often very time consuming. Costs are generally more than PC’s but less than mainframes. In our opinion, mini computers, as a tool for MMS’s are rapidly being replaced by networked PC’s.

- **Mainframe Computers.** The advantages of mainframe computers are their ability to handle large fully integrated systems and their ability to handle massive amounts of data. Their disadvantages, as a tool for MMS, are very serious. They are very expensive, software choices are limited and expensive, and modifications to software are expensive and time consuming. Implementations generally require more than a year. The systems are inflexible because changes will affect many using departments and arriving at consensus is usually very difficult, hence changes tend not to be made. The users have the feeling that they are being controlled by the computer and not by their own management needs. Therefore, many expensive systems have fallen into disuse, even though the paper continues to flow.

Selection of a computer and computer system is not a simple matter. The computers and software available are still changing rapidly. Matching what is
available with the needs of the port requires the services of a person who is both familiar with current developments in computers and the needs of the maintenance department. Most ports should utilize the services of an outside consultant.

8.3 Essential Elements

There are many different formats and configurations which can be successfully used to apply an MMS. But a complete and effective MMS for a port should include the following elements:

- **Operating plans and budgets.** Annual and monthly plans project equipment operations, equipment availabilities, maintenance manpower requirements, new maintenance equipment requirements and maintenance cost. The plan begins with the port operating plan, from which the maintenance plan can be developed. Control points are identified. Refer to section (12.2).

- **Coordination with operations.** The maintenance and operations departments must effectively coordinate their activities working toward common goals (12.0).

- **Operating statistics.** Reliable equipment operating data, such as hours of operation, tons handled, number of moves, idle hours, utilization, etc. are essential to good fleet management. Many ports lack a system to collect and accumulate these data.

- **Work order.** This is a method of defining maintenance work which is to be done and of communicating same to the people who will perform the work. A sample work order is presented in Figure 8.3.1.

- **Job card.** The job card is a means of combining a number of work orders into one job and controlling them as one job. Figure 8.3.2 includes a typical job card format.

- **Work history.** A history of all work performed on each unit of equipment and each major repairable component.

- **Cost collection.** Job costs are accumulated for each work order.

- **Work planning.** This includes identifying the methods and procedures to be used to do the work; identifying the tools, equipment, manpower, and spare parts required and assuring that all are available before the work is started. It also includes estimating the costs and time required to complete the work. Work planning is normally done on the work order.

- **Work backlog.** All pending work is prioritized and identified by work order and can be sorted by priority, equipment unit, supervisor, or trade. The backlog is one of the most important elements in a maintenance management system. It is the essential ingredient for scheduling work on equipment units.
Work scheduling. A systematic method of scheduling work makes use of the information in the work backlog, equipment availability plans and operating plans to prepare weekly and shift work schedules. Close coordination between operations and maintenance departments are involved. Personnel performing the work clearly understand what they are expected to produce. A daily schedule format is displayed in Figure 8.3.3 as an example.

Standards of expectation. The system should allow planners to input standards of expectation for all performance measures, including standard work times, labor hours, and material usage for repetitive jobs. A typical standard data sheet is included in Figure 8.3.4.

Performance monitoring. There is a system for comparing actual results with plans and schedules. Comparisons are made on both short term (shift by shift) and longer term intervals. Results are reported to all levels within the organization. Each level receives information on his full scope of responsibility in such detail that he can monitor the variables which he can control. (6.2).

Preventive maintenance. This involves a systematic identification of preventive maintenance tasks and frequencies which should be performed on each unit of equipment. Weekly schedules of work to be completed are prepared. Equipment faults which are detected during PM inspections are fed into the work order system (10.0).

Predictive maintenance. Based upon monitoring of equipment condition and predetermined long term schedules, replacement of components and other major maintenance tasks are scheduled (10.0).

Component tracking. Repairable components should be tracked so that a history is maintained on each component unit. The current whereabouts of each unit should be known.

Spare parts and materials. Maintenance personnel should be able to easily determine which spare parts will be required for a project and the availability status of the parts involved. The system should facilitate the procurement of the materials, either from an internal stock or from vendors. As an example, one page of a parts "catalog" which identifies the parts used on each unit of equipment is shown in Figure 8.3.5

Material control. Maintenance will not function well if there is not a good system in place for purchasing parts and materials and for managing the inventory.

Cost accumulations. Costs should be accumulated and reported for each equipment unit, groups of equipment and responsibility area.

Failure analysis and warranty control. Recurring failures need to be investigated to determine cause and solutions. Failures which are covered by a supplier's warranty must be monitored so that appropriate
recovery is received from the vendor. Without a good system of monitoring equipment, and component, warranty status, it is quite likely that viable warranty claims will be overlooked.
## WORK ORDER

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<th>LOCATION</th>
<th>COST CODE</th>
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**Requested By:**

**Contact No.:**

**Date Submitted:**

**Date Required:**

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<th>Priority</th>
<th>Purpose</th>
<th>Reason for Failure</th>
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- [ ] Emergency
- [ ] Urgency
- [ ] 1 Week
- [ ] Next P.M.
- [ ] 2 Weeks

**Description of Work Required**

**Total Actual Hours:**

**Cause of Failure**

**SUPERVISOR:**

**Parts Not Planned**

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**SERVICE METER READING:**

**Location:**

**Component Name:**

**Component Sn. Removed:**

**Location:**

**Component Sn. Installed:**

**Location:**

**Component Sent To:**

**Date Work Order Completed:**

**Recommendations to Improve This Job**

**Special Tools and Equipment**

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**Material**

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**Labor**

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**Special Instruction/Safety Requirements**

**Total Hours:**

**Pre-Release Checklist**

**Person Making Check:**

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**Figure 8.3.1**

117
## JOB CARD

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<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>ACTUAL INS.</th>
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**Equipment No.:**

**Equipment Description:**

**Total Op. Hrs.:**

**Inspection Date:**

**Inspected By:**

**Task Description:**

**PM:**

**Actual Ins.:***
## DAILY MAINTENANCE WORK SCHEDULE

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<th>ACT. H/H</th>
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Figure 8.3.3
Figure 8.3.4

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SPECIAL INSTRUCTIONS/SAFETY REQUIREMENTS

SPECIAL TOOLS AND EQUIPMENT
Figure 8.3.5

TYPICAL PAGE OF A PARTS CATALOG

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K330-41-01 CONVEYOR, FINE DYE TRANSFER NOs

** no component

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**REDUCER**

**speed**

- Component part number is 470725 | BOLDE | BOLDE | T7725 | 1 EA |
- BEARING, CORE BACKSTOP | 395437 | BOLDE | BOLDE | T7725 | 1 EA |
- BEARING, CORE COUNTERSHAFT | 391950 | BOLDE | BOLDE | T7725 | 1 EA |
- BEARING, CORE DIAP | 395373 | BOLDE | BOLDE | T7725 | 1 EA |
- BEARING, CORE OUTPUT | 391962 | BOLDE | BOLDE | T7725 | 2 EA |
- BEARING, CUP BACKSTOP | 390438 | BOLDE | BOLDE | T7725 | 1 EA |
- BEARING, CUP COUNTERSHAFT | 391951 | BOLDE | BOLDE | T7725 | 1 EA |
- BEARING, CUP DIAP | 390333 | BOLDE | BOLDE | T7725 | 1 EA |
8.4 Material Supply

Supply of spare parts and material for equipment is an essential link in the maintenance and equipment management chain. It is of major financial and operational importance. Spare parts inventory value can equal 25%, and more, of the equipment value. The annual cost of spare parts ranges between 20% and 45% of the total maintenance budget.

Most importantly, extensive delays to the repair of vital equipment are caused by lack of the necessary parts and materials. This is universally common in LDC ports; even those ports which, in other respects, perform effectively. An expedient reaction to this problem is evident in many ports. That is cannibalization, the practice of taking parts from one "down" unit of equipment to repair another. This is a self defeating approach since the cannibalization continues until the equipment unit is never restored. Therefore, the size of the fleet has been reduced. Cannibalization is a practice which may be advantageous only in exceptional circumstances. It should, therefore, only be engaged in if very carefully controlled by a good management.

Common problems which contribute to lack of parts include:

- Lack of foreign exchange.
- Lack of forward planning of parts requirements.
- Governmental restrictions and approvals.
- Port internal delays in issuing purchase orders.
- Errors in maintaining inventory records.
- Inappropriate stock replenishment logic and inventory management procedures.
- Misinterpretation of manufacturer’s parts catalogue and maintenance manuals.
- Lack of coordination in the store’s operating hours with the maintenance department operating hours.
- Store keeping staff often lacked the necessary skills and training.

It is clear that an effective materials management program is vital to the functioning of the maintenance department. An effective program will include the following features:

- An adequate supply of funds, in accordance with approved budgets.
- Well established lines relationships with suppliers.
A system whereby the using department, in this case maintenance, forecasts usage of individual items.

A well defined system of placing purchase orders, without undue delays and bureaucratic approvals.

A functioning system of tracking order progress and expediting where necessary.

A well controlled delivery system, including tracking and expediting.

A system of recording receipt of material, including inspections where appropriate, and timely payment of suppliers' invoices.

Adequate storage facilities which protect the stocked material from physical deterioration or damage and which allows efficient storage and retrieval. Air conditioning is essential in many climates to preserve the quality of certain spares.

Stock which is secured from unauthorized access, to avoid theft, damage, and unrecorded transactions.

A simple and effective means of finding items which are carried in stock.

A logical and controlled system of determining which spare parts and material items are to be carried in inventory stock.

A system of maintaining accurate records of the stock on hand for each item in the warehouse, and the ability to quickly determine the quantity on hand and the quantity on order, by the maintenance department as well as the stores department.

A logical system of determining the economically optimum time when an order should be placed to replenish stock, for each item, and the quantity which should be ordered.

A system of controlling and issuing stores items to the using department and charging the costs to the appropriate work order.

A consistent, and continuing, program of physically counting items in stock to ensure the veracity of the inventory records.

A system to dispose of stock items no longer required.

A well trained materials staff.

The stores should be staffed all hours that the maintenance departments schedule significant work. If, for instance, the maintenance shops operate three eight hours shifts per day, seven days per week, then the stores should be open for service around the clock also. If warehouse staff is not present
during these hours, it will become necessary for maintenance department personnel to enter the warehouse to retrieve parts and materials. There is a high risk that they will neglect to record the material they have taken which will result in a condition where the warehouse has less material than their records show. This ultimately results in stock outs or unsatisfied demands. The maintenance function ultimately suffers.

Since demands at the warehouse are often "slow" on night shifts and weekends, it is necessary to schedule some other work to be performed by the warehouse persons on duty. Counting stock, placing received material into bins, cleaning, etc. are the type of duties which can be scheduled for these slow shifts. In this way, inefficient usage of manpower can be avoided.

Fuels and lubricants bear individual mention, since for many LDC ports they must be imported and represent a major demand on foreign exchange. Some ports are beginning to meter fuel to individual machines and to link consumption with operating hours to better control the consumption of fuels.

Lubricants should be standardized to the extent possible, so that minimum quantities are carried in stock. Equipment suppliers will identify the lubricant specification which should be used. Experienced lubricant specialist should make a survey of the lubricants required by each type of equipment. In that way total requirements of each lubricant specification can be made known to suppliers at the time that they bid for supply contracts.

It is essential to install adequate equipment for dispensing oils and lubricants and to ensure that this is properly maintained otherwise heavy wastage will result.

8.5 Maintenance Facilities and Equipment

Many LDC ports utilize substandard facilities for maintenance purposes. The maintenance department is often required to use whatever buildings happen to be available. They may be scattered and sometimes far from the equipment to be maintained. Space and lifting facilities are inadequate. Conditions are dirty and cluttered. Maintenance tools and equipment are often unsuited to the work to be done.

With the increasing reliance on sophisticated cargo handling equipment, it is essential that adequate and appropriate facilities are provided to the maintenance department. Maintenance facilities should include the following features:

- Adequate space for equipment to be worked on, including sufficient clearance overhead and adequate doorways.
- Protection from dust and severe weather elements.
- Protection from salt spray and corrosive atmosphere.
- Adequate lifting devices/inspection pits.
- Close proximity between equipment repair facilities and equipment working areas.

- Distinct separation between conflicting tasks. (i.e. separate areas for: washing/steam cleaning; greasing/oil change; blacksmith work; injector maintenance; electronics repair; etc.)

- Close proximity between repair facilities and stores.

- Diagnostic and repair tools appropriate to the equipment being maintained and appropriate to the level of maintenance being performed.

- Sufficient space for shop tools and routine maintenance consumables storage.

When new cargo handling equipment is being acquired, the adequacy of repair facilities and equipment must be compared with the cargo handling equipment requirements. If there is a deficiency, the necessary funds should be justified along with the funds for the new equipment. If the advantages of purchasing the new cargo handling equipment will not justify the expenditure for necessary maintenance facilities, the equipment should not be purchased.
9.0 INTRODUCTION OF A MAINTENANCE MANAGEMENT PROGRAM

Implementation of a maintenance management program normally involves the introduction of a computerized management system and changing the methods of management, supervision, and planning which are utilized in the maintenance department. On some occasions, however, the problems may go beyond the management techniques. Craftsmen may require technical training, facilities may be inadequate, available funds may be inadequate, etc. In fact, there may exist a broad range of problems so extensive, that it is virtually impossible to solve them all at once. In such cases, it is necessary to identify those problems which are most critical to the operation and to assess the time and resources required to solve each of these problems. With this knowledge in hand, port management should rank the problems by priority and develop an action plan which attacks the highest priority problems first. Outside assistance should be utilized to accelerate the pace with which problems are solved.

The following paragraphs review the steps required to develop and implement a maintenance management system and are written as though the port has no formal maintenance management system in place. Existing ports will almost certainly have some aspects of maintenance management system functioning, with or without a formal policy. Therefore, the reader must recognize that some portions of the following steps may not be required in his situation.

The sequence of steps, in the process, are generally as they appear below. A typical program implementation schedule is demonstrated in Figure 9.0.1.

Figure 9.0.1 is intended to illustrate the steps required to successfully implement a Maintenance Management Program. The first two bars on the chart represent the design and construction of the maintenance facilities. Since it is impossible to generalize on facilities, these two bars represent an undetermined span of time. The chart indicates that development of program should commence well in advance of the facilities going into service. This lead time will vary from port to port, and the 8.5 months shown here is for illustration purposes only.
9.1 Planning the Program

Once the policy decision has been made to install a maintenance management system, the first step will be to plan the system and how it will function in detail. Many system implementations have failed because they were not sufficiently planned. The result was that either the implementation was not completed before funds and patience ran out or, if implementation was completed, the system did not function properly and it fell into disuse. Senior management should insist that the planning is adequate.

Following is a listing of activities that should be covered during the planning phase:

- Identify the problems and needs. A detailed analysis of the existing maintenance operation.

- Define the objectives. State clearly the objectives of the system; in other words answer the question, "What is to be accomplished that will justify the cost of the system?"

- Define the features. List all of the functions which you wish the MMS
to accomplish. Refer to the checklist of "essential elements" in section 8.3. If your port has need for other features, define them at this point.

- **Identify existing procedures to be retained.** Introducing a new MMS requires major changes in the way things are done. Procedures which currently work well should be retained if they can be incorporated into the new system. The amount of change should be minimized.

- **Prepare a conceptual description of the system.** This description should briefly, but clearly, describe how the system will work, what it will do, the reports that will be produced, and how it will impact on each level and each department in the organization. This description can be used to ensure that management will get what they expect from the system and to ensure that each department understands and accepts their role in making the system work.

- **Select data handling method.** Based on the definitions established above, select the method which will be used for handling data and making calculations. If a computer approach is to be used, select the computer and software. We recommend keeping it simple wherever possible. The computer is a tool used in a management system. It is not the most important ingredient. It must be kept in that perspective.

- **Prepare a detailed work plan.** Identify each task which must be completed, identify the resource which will perform the task, estimate the time required for each task, and organize the sequencing of tasks into a workable schedule. In this activity it will be necessary to quantify much of the work, e.g. estimate the number of PM checklists which must be prepared, estimate the number of spare parts (line items) which must be cataloged, estimate the number of units of equipment which must be put into the system, etc. Unless such detail is developed, the estimates will not be reliable and the danger is that substantial overruns in cost and time will be incurred. Sufficient resources will be required to continue to manage the day to day maintenance activities while also developing and implementing the new system. Be sure that adequate resources are applied to both. Outside assistance may be required. (14.0)

- **Estimate the time and costs of implementing the system.** Submit a realistic estimate to management for their approval. Implementing a maintenance management system will represent a significant cost expenditure. It is better that management knows this in advance. Implementation projects have been abandoned in mid stream when management sees a major overrun with "no end in sight".

### 9.2 Preparing the Program

The next phase will consist of preparing the data, computer programs, and manual procedures which will be required. This will include the following tasks:
- Prepare the maintenance department plan. Based on the master operating plan calculate equipment operating requirements and subsequently maintenance department activity and resource requirements.

- Establish individual objectives for the various sections of the department. Express the objectives in the indices which will serve as the performance measures.

- Create, modernize or expand the workshops and stores facilities.

- If a computer system has been chosen, have the system installed and key people trained in the use of it.

- Design the maintenance reports which will be used.

- Establish work order, backlog control, planning and scheduling procedures.

- Prepare Preventive Maintenance (PM) checklists and schedules, or scheduling criteria, for each unit of equipment and integrate into the system.

- Prepare predictive maintenance tasks and schedules, or scheduling criteria and integrate into the system.

- Enter spare parts data.

- Organize equipment data and enter.

- Organize equipment vendor manuals and engineering documents into readily accessible files.

9.3 Implementing the Program

After preparation of the program all that remains is to begin its use. This is perhaps the most critical phase, since the program will not accomplish the intended results unless the people in the organization use it and perform their functions properly. Since the new program will inevitably represent change from the "old ways of doing things" there will be resistance by some people to make the changes. Therefore, the implementation phase must develop "enthusiasm" throughout the organization. Among the tasks which are necessary are:

- Assign responsibility and designate duties for operation of the system.

- Train personnel; planners/schedulers, maintenance technical staff, maintenance foremen, craftsmen, operations supervisors regarding the system and each individual's role in it. Stress the benefits of the system to the port, the benefits to the individual in performance of his job, and the importance of each individual performing his job properly.
- Train supervisors and technical staff in problem identification and problem solving.

- Begin using joint planning, scheduling and forecasting meetings between the maintenance and operations department.

- Monitor closely the execution of the system. Take corrective action where necessary. Continue close monitoring until the program is operating smoothly and effectively for at least one year, with periodic reviews thereafter.

9.4 Managing the Program

Introduction of a maintenance management program is complex, time consuming, and costly. It should be managed as a project much as a major facility modification project. Responsibilities for each task in preparation and implementation should be clearly assigned. Progress against schedules should be closely monitored. Make the line maintenance managers responsible for successful implementation.

9.5 Resources Needed for the Program

Since this is a major project, management must recognize that there must be a significant commitment of resources (people, time, money, foreign exchange, computing equipment) to the project. To the extent that the port has qualified maintenance personnel, it will be desirable to utilize them in development and implementation of the system. If this is the case, it should not be assumed that they can continue to perform their existing duties in addition to the new project. They must be relieved of existing responsibilities or they will not have the time available to develop the new project in a timely manner. The implication of this is that there must be competent replacements.

It often happens that a port does not have sufficient qualified people to continue to operate and introduce a new system. The solution is to utilize outside resources. There are consulting firms which specialize in developing and implementing maintenance management programs. Such firms can either work as team members with a task force of port personnel or they can develop the program and then train port personnel in its use. Either option can work well and the choice usually rests on the capabilities that the port has within its own organization.

A second reason for utilizing a specialist firm is to gain the benefit of experience gained over many previous installations.

Perhaps the most important resource required is a complete commitment to the program on the part of senior port management.
Preventive maintenance consists of a number of activities which are designed to avoid or minimize expenditure of resources for repair of equipment. The preventive activities are relatively inexpensive in relation to the equipment failures which they are intended to prevent. These activities include inspection, adjustment, lubrication, nondestructive testing, and part or component change out. These activities fall into two general categories:

- **Preventive maintenance** (PM) activities are intended to prevent catastrophic equipment failure, undetected wear, premature component failure, and substandard equipment performance. Inspections are performed in sufficient frequency that minor defects will not have had an opportunity to inflict serious damage to the equipment between inspections. Adjustments are performed frequently enough to ensure that the equipment operates properly. Lubricants are replaced at intervals which will assure that lubricated moving parts will not "run dry" and that lubricants will not have had the opportunity to become unduly contaminated or deteriorated. These activities are normally scheduled at predetermined time intervals. In the case of fixed equipment the interval will normally be calendar units such as days, weeks or months. Mobile equipment intervals will usually be expressed in operating hours. In either case the intervals are set, not in anticipation of wear, but in anticipation that significant wear or damage (excluding accidents) will not have occurred between PM events.

- **Predictive maintenance** activities, on the other hand, are performed in anticipation of wear. These activities are applied to equipment components or parts which encounter wear or stress at a constant rate. The rate can be identified with units of work or equipment activity. Thus a failure or exhaustion time can be predicted within a reasonable time range. Component or equipment units of work, such as container moves, component hours operated, etc. are tracked and the appropriate activity performed well in advance of a "predicted failure". At that point an inspection is performed to determine if the component should be changed out.

The effectiveness of the entire maintenance program is proportional to the quality of the preventive/predictive maintenance program. The effectiveness of the preventive/predictive program is dependent upon the frequency and intensity of the inspections and services.

10.1 **Preventive Maintenance (PM) Check Lists**

The first primary element in a preventive maintenance system is the "check list." This is a document which identifies the specific tasks which are to be performed at each service interval for each unit of equipment.

Effective PM check lists must be developed for all PM activities. Without these check lists and the necessary instructions the program is
impossible to adequately control and will result in eventual collapse.

The ideal PM check list will list the specific actions which are to be taken by the craftsman on a specific unit of equipment. Each action is followed by a tick box in which the craftsman indicates that the action has been taken. Adequate space is provided for the craftsman to enter any appropriate comments concerning the condition he found and corrective action required. An example check list is shown in Figure 10.1.1.

Checklists include those tasks which can be performed by a single craftsman. If electrical PM tasks are performed by an electrician and mechanical PM tasks by a mechanic, two separate check lists would be prepared.

Whenever possible, PM tasks should be active; that is corrections to identified problems should be made on the spot provided they can be completed within the time allowed for the PM service.

During PM services, wherever appropriate, measurements should be required on the check list. For example, it is much more effective to define a task as "record hydraulic system pressure" rather than "check hydraulic system pressure". This has two advantages. There is more assurance that the craftsman will actually perform the task rather than simply placing a check mark on the form, without having made the inspection. It also provides information to the maintenance supervisor and staff about the condition of the equipment.

In the example discussed above it will also be appropriate to require an adjustment if the pressure is out of limits.

When it is not possible to correct deficiencies on the spot, during a PM service, a comment must be entered on the check list indicating the nature of the defect and the corrective work required, provided the craftsman is able to make that determination. The supervisor and/or the maintenance planner then generates a work order to perform the corrective work at a later date. (The maintenance planner's functions are discussed in section 6.1)

Completed PM check lists are returned to the appropriate maintenance supervisor for his review and then to the maintenance planner. In this way the PM program will become a vital link in the continual effort to maintain an up-to-date backlog of outstanding work required on each unit of equipment. Significant findings are recorded in the equipment history files.

The use of oil analysis should also be emphasized, as oil analysis provides an excellent means to monitor the condition of critical components, especially hydraulic systems and engines. Particularly, those analysis systems which are coupled to "Expert Systems" which provide excellent data on the performance and corrective action needs.
<table>
<thead>
<tr>
<th>COMPONENT OR PART</th>
<th>MAINTENANCE PROCEDURE REQUIRED</th>
<th>NOTE/COMMENTS ON PROCEDURE</th>
</tr>
</thead>
<tbody>
<tr>
<td>BEARING(s)</td>
<td>CHECK BEARING TEMPERATURE WITH HAND THERMOMETER RECORD READING.</td>
<td>Deg.f.</td>
</tr>
<tr>
<td>PILLOW BLOCK</td>
<td></td>
<td></td>
</tr>
<tr>
<td>BELT</td>
<td>WITH BELT RUNNING CHECK FOR UNUSUAL VIBRATION.</td>
<td></td>
</tr>
<tr>
<td>CONVEYOR</td>
<td>ENSURE BELT IS TRAINING PROPERLY.</td>
<td></td>
</tr>
<tr>
<td></td>
<td>ENSURE NO EXCESS MATERIAL IS BUILT-UP UNDER BELT OR AT TRANSFER POINT(S). REPORT CONDITIONS YOU CAN NOT CORRECT.</td>
<td></td>
</tr>
<tr>
<td>COUPLING</td>
<td>CHECK FOR NOISE, SUCH AS KNOCKS, GRINDING OR ANY UNUSUAL OPERATING CONDITION.</td>
<td></td>
</tr>
<tr>
<td>DRIVE</td>
<td>INSPECT FOR ANY UNUSUAL NOISE, VIBRATION AND OIL LEAKS. NOTE ANY UNUSUAL CONDITION.</td>
<td></td>
</tr>
<tr>
<td>GEARBOX</td>
<td></td>
<td></td>
</tr>
<tr>
<td>SPEED REDUCER</td>
<td></td>
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</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>GUARD(s)</td>
<td>ENSURE ALL GUARDS ARE IN PLACE, IN GOOD CONDITION AND FIRMLY POSITIONED.</td>
<td></td>
</tr>
<tr>
<td>COUPLING</td>
<td></td>
<td></td>
</tr>
<tr>
<td>CARRIER</td>
<td>INSPECT IDLERS FOR SLUGGISHNESS OR STALLED CONDITION CHECK MOUNTING BRACKETS. LOOK FOR BAD SEALS AND BEARINGS.</td>
<td></td>
</tr>
<tr>
<td>IDLERS</td>
<td></td>
<td></td>
</tr>
<tr>
<td>RETURN</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

ENTER A NOTATION ON CONDITION FOUND DURING INSPECTION: ________________

NOTE: OK = IN GOOD CONDITION, DN = DEFECT NOTED, DR = DEFECT REPAIRED. DATE COMPLETED: ________________
10.2 Preventive Maintenance Intervals

The second important element in preventive maintenance is the interval which elapses between PM services. The interval should be designed so that defects or maladjustments are detected early enough to avoid significant equipment damage or degraded equipment performance. The defects normally detected in a PM check are not predictable as to their rate of occurrence. Therefore, determining the appropriate interval for a specific task should be based on experience. The sources of this experience will be the manufacturer of the equipment, other ports, or other operations, which operate similar equipment in similar conditions, and your own port's experience. It is often found to be necessary to adjust intervals as experience is gained. The approach to be followed with new equipment is to set the intervals on the safe side and gradually lengthen them as experience indicates. Caution must be exercised so that extending PM intervals does not nullify the terms of an equipment vendor's warranty.

Intervals determine the number of check lists required for each unit of equipment. All tasks which are to be performed at the same interval will be included on the same check list. Tasks to be performed at different intervals must be on separate check lists; e.g. a 250-hour straddle carrier mechanical PM checklist would list all tasks required to be performed each time an additional 250 hours have been accumulated on each unit. The checklist may contain several pages.

Since each interval will require the equipment to be scheduled down for PM service, it is appropriate to minimize the number of different intervals which apply for a given unit of equipment. If, for example, several tasks have 250-hour intervals and others have 275 hour intervals, it is logical to incorporate the 275-hour tasks into the 250-hour PM service.

Intervals are expressed in generalized terms for each type of equipment. The counting unit should be easy to monitor. Most common counting units are operating hours for mobile equipment and working days for fixed equipment, such as a conveyor system. Passenger vehicles might logically use miles driven as the counting unit, but many operations find that the expense involved in monitoring miles driven, on a current basis, is significant and they can accomplish essentially the same result by using working days which is an easy counting unit to monitor.

10.3 Predictive Maintenance

There are many similarities between predictive and preventive maintenance. The difference is in the predictability of wear characteristics. Predictive maintenance is directed at those components or parts of equipment which have a reasonably predictable service life, recognizing the amount of work which the component performs. This implies that it is necessary to count and accumulate the units of work performed by the component. Examples are "container lifts by a set of crane hoist ropes" or "hours operated by a diesel engine". In both cases it is necessary to keep track of the cumulative units of work performed by that component, not the equipment unit. When a new, or rebuilt, engine is installed in a straddle carrier, it is necessary to begin
counting at zero when the unit is put into service, regardless of the number of hours on the straddle carrier itself.

This creates an additional recordkeeping job, which a maintenance management system should do. The service life intervals are, however, usually quite long so that it is not necessary to monitor the accumulated work units on a daily basis. In most cases, weekly updating is sufficient.

The action which is taken in predictive maintenance usually involves a significant amount of work. It may involve an automatic replacement of the component or an inspection. The inspections usually involve disassembly or nondestructive testing methods. (If the inspections are relatively easy to perform, they will usually be included in the preventive maintenance tasks.)

Typical components which will be included in the predictive program include:

- For Mobile Equipment:
  - Engines.
  - Turbos.
  - Transmissions.
  - Planetaries.
  - Differentials.

- For Cranes:
  - Hoist ropes.
  - Spreader twist locks.
  - Crane structural members.

10.4 Scheduling of Preventive and Predictive Maintenance

Preventive or predictive maintenance work would theoretically be performed at the moment that the assigned interval has been reached. There are, however, complications. That moment may not be convenient either to the equipment user or the maintenance department.

Generally, preventive work should be scheduled during periods when the cargo handling demand is the lowest. Corrective and major component change-out work on mobile equipment fleets should be scheduled around the clock to minimize the time that equipment is down "waiting to be worked on."

PM work on fixed equipment, which experiences intermittent use, is normally scheduled for a time close to the elapsed interval during periods of scheduled downtime, i.e. not required for operation. A typical example is a
quayside crane. It is especially important that this work be scheduled during
down periods, between ship and/or cargo handling operations, which are long
enough to ensure completion of the work before the equipment is required by
the user again.

The best method of scheduling maintenance is for the operating
deptartment to quantify their needs on the basis of their operating
requirements. This quantification is derived from the Master Operating Plan
(12.2). Each productive requirement is unitized; e.g. if a crane must load
"x" number of containers and the unitized factor is 30 container moves per
hour, an extension defines the number of hours required. Once the forecast of
equipment hours required has been made, maintenance planning personnel can
coordinate with the operating department to schedule those equipment items
which are allocated to production and those required for PM.

Mobile equipment does not usually have extended down periods scheduled.
One of the primary keys to high mobile equipment availability is to make
optimum use of the service time available. To accomplish this, the following
concepts are suggested:

- Equipment is prescheduled into the service bay with prior arrangement
  and agreement with the operations department based on weekly PM forecast
  meetings.
- Minor defects should be selected from the backlog of work for that unit
  and scheduled for completion while the equipment is down for PM.
- Filter kits and frequently required service parts should be prepackaged
  and readily available at the service location.
- All major services are performed in a centralized area to reduce travel
time and unnecessary production loss.
- All minor defects identified are repaired immediately where possible.
  If the defect cannot be corrected immediately during the scheduled down
  period, a work order should be prepared and added to the backlog of work
  for that unit. It is scheduled at a later date when all of the
  necessary parts and tools will be readily available. Major and safety
defects are brought to the immediate attention of the maintenance
  supervisor. The operations department is advised if there will be a
delay in returning the equipment.
- Equipment should be returned to the operations department when
  originally scheduled. Consistent delays in returning equipment will
  make it difficult for the operations department to release equipment in
  the future because they will not be able to depend on getting it back
  when promised.
- Planning clerical work and historical documentation is handled by a
  planner and appropriate clerical personnel to allow the maintenance
  supervisor more time to devote to overview, directing and controlling
  the work.
10.5 Preventive Maintenance Control

One of the great risks with a preventive maintenance program is disuse or incomplete use. Well conceived and developed programs are of no value unless the organization utilizes it properly. Therefore management must maintain the necessary controls to ensure proper application of the program. A PM control model is displayed on Figure 10.5.1. The essential elements include:

- Utilization of PM schedules and check lists.

- Periodic reports are issued indicating the extent to which PM services are performed in accordance with schedules. If they are not consistently performed as scheduled, corrective action is required. The problem may either be in the maintenance department which is unable, for some reason, to complete the PM work, or in the operations department which is unwilling to release equipment as scheduled. If the problem persists, top management must determine the fundamental cause(s) and take corrective action. Without an effective PM program equipment demand availability and maintenance efficiency will be unsatisfactory.

- The maintenance supervisor reviews all completed check lists to be aware of equipment conditions which were found and to ensure that the necessary work orders are raised. He also follows through to ensure that the corrective work is completed in a timely manner.

- The maintenance supervisor performs random checks of machines after PM service is completed to ensure that the PM work has been properly done.

- When breakdowns occur a maintenance engineer or supervisor analyses recurring failures, reviews the most recently completed PM check lists, and reviews the maintenance history of the equipment or component to determine the fundamental cause(s) of the failure. Corrective action is taken, as required. In some cases changes in the PM program may be required. In others changes in equipment operation practices or equipment design changes may be the solution.

It is important that corrective action, which is indicated by the above described control system, be taken. The best Preventive Maintenance system will fail if the maintenance department is unable to correct the faults found. Senior management must ensure that all of the necessary resources, including foreign exchange for purchase of repair parts, is available. Senior management should also monitor trends in the size of the work backlog, especially the high priority items.
Figure 10.5.1

MECHANICAL PM CONTROL MODEL

IMPLEMENT PM SCHEDULE AND CHECK LISTS

CONFIRM COMPLIANCE

WHEN BREAKDOWN OCCURS

REVIEW COMPLETED PM CHECK LISTS

RANDOM CHECKS OF MACHINES AFTER PM COMPLETED

PERFORM FAILURE ANALYSIS

REVIEW MOST RECENT PM CHECK LISTS

REVIEW EQUIPMENT & COMPONENT HISTORY

TAKE CORRECTIVE ACTION
11.0 MAINTENANCE MANAGEMENT AND ORGANIZATION MANUAL

This section defines the information which should be included in a maintenance management manual and in a maintenance organization manual. These topics may be covered in a single manual or in two separate manuals as the individual port may desire.

The topics fall into three primary categories:

- Organization structure.
- Individual job performance.
- Maintenance strategy, policy and procedures.

11.1 Organization Structure

Each position in the maintenance department should be defined in a formal job description. A job description will include:

- Basic purpose of the position.
- Scope of the position's responsibility stated as explicitly as possible.
- Reporting relationships. It will identify the position to which this position reports and those which report directly to this position. It will also define the relationships with others such as the working relationship between a maintenance planner and a maintenance supervisor where neither reports to the other but one actively supports and assists the other. In such cases, care should be exercised to ensure that one position or the other has ultimate responsibility for accomplishment of results and that responsibility is not shared.
- The performance measures which will be used to judge the position incumbent's performance. (This subject is discussed further below.)

Position descriptions are made readily available to the incumbents of the position so that there is no confusion as to what is expected of them. In fact, department management and supervision must ensure that each incumbent understands the applicable position description.

The manual should include an organization chart which graphically illustrates the reporting relationships. The number of personnel authorized for each position should be shown.

11.2 Individual Performance

As indicated in section 6.2, Performance Based Criteria, individual performance should be assessed on the basis of objective, usually quantitative, information. The performance measures or indices which will be used to measure the performance of the incumbent, in each position, should be
identified in the position description.

Periodically, the incumbent and his superior will jointly establish the values for each index which will represent the incumbent's goals for the coming period. This is not to say that the incumbent will have a free hand in establishing his own goals. The superior will normally have the greatest influence in establishing the goals. But it is essential that the incumbent makes a commitment, in his own mind, to achieve the goals. Without such a commitment he will not put forth his best efforts. Unless he believes that the goals are achievable he will not make such a commitment. Therefore, the burden falls on the superior to ensure that the goals he asks for are achievable and that he is able to convince the incumbent of that fact.

The incumbent, as well as the superior, must have readily available the actual results for each index on a continuing and timely basis. The incumbent needs this information soon enough to take corrective action. In other words, he must be able to influence the results before it is too late. (See section 6.2 relative to frequency of index measurements at different levels within the organization and for discussion of performance criteria.)

Each incumbent should periodically receive an evaluation of his performance by his superior. The evaluation should be based primarily on the results of the performance measuring indices. There must be a formal program of performance evaluation. Many supervisors do not enjoy making performance evaluations. Therefore, senior management must actively ensure that the performance evaluation program is followed and that the evaluations are objective.

An incumbent's rewards should be directly related to his performance. His compensation and opportunities for promotion and broadening of scope should be directly determined by his performance. Everyone in the organization should be aware that this practice is followed.

11.3 Maintenance, Strategy Policy and Procedures

This section of the manual will communicate throughout the maintenance department an understanding of what the department is expected to accomplish and the ways the department will go about its work. It will include:

- Strategic objectives as discussed in section 3.1, Objectives.

- A statement of maintenance policies.

- Computing options which are to be applied.

- Scope of the facilities to be maintained by the department.

- Maintenance facilities to be utilised.

- The level of maintenance to be performed by the department. This will include criteria to be used in determining whether any particular work should be performed in-house, or by using an outside maintenance
contractor (OMC).

- Maintenance procedures. This will include:
  * Work order preparation, authorization, completion, and recording.
  * Backlog maintenance and use.
  * Preventive and predictive maintenance.
  * Material procurement and return.
  * Work planning.
  * Major overhaul planning.
  * Work scheduling.
  * Manpower requirements determination.
  * Training programs.
  * Work order and equipment maintenance costing.
  * Equipment replacement.
  * Maintenance department reports.

If the department is using a computerized maintenance management system, the user's manual for that system will, in many respects, overlap with these procedures. Careful cross referencing may be used to avoid duplication and, potentially, contradiction between the two manuals.
12.0 THE RELATIONSHIP BETWEEN PORT OPERATIONS AND MAINTENANCE

Unless the port operations and maintenance departments work cooperatively toward the common basic objectives of the port, the maintenance program will be chaotic and ineffective at best. The best starting point for establishment of common objectives is a port master operating plan.

12.1 Equipment Allocation and Usage

Maintenance performance, in a port, is influenced to a very great extent, by the manner in which equipment operators operate the equipment. In many LDC ports most equipment operators do not properly care for the equipment. Improper operating procedures cause damage and excessive wear. Poor housekeeping practices cause accidents. Generally, the ports lack well conceived and clearly understood operating procedures. Improved operating procedures and improved operator training is urgently required.

Equipment operators must accept responsibility for equipment while it is under their control. They should be accountable for damage and accidents. Every operator should conduct a brief inspection and acceptance of the equipment at the beginning and end of each shift. In that way damage responsibility can be identified. More importantly the individual operator has an increased sense of responsibility.

### EQUIPMENT RUNNING COSTS AT SELECTED PORTS, AND THEIR RELATIONSHIPS TO PORT OPERATING COSTS AND REVENUES

<table>
<thead>
<tr>
<th>Port</th>
<th>Annual Equipment Running Costs ($ millions)</th>
<th>Running Cost as % age of Port Operating Costs</th>
<th>Running Cost as % age of Port Operating Revenue</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>5.1</td>
<td>12%</td>
<td>7%</td>
</tr>
<tr>
<td>B</td>
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<td>10%</td>
<td>8%</td>
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<tr>
<td>C</td>
<td>15.0</td>
<td>10%</td>
<td>6%</td>
</tr>
</tbody>
</table>

Table 5.5.2B Average Equipment Running Costs at an LDC Port (in $ Equivalent)

<table>
<thead>
<tr>
<th>Equipment Type</th>
<th>Driver Costs (Estim.)</th>
<th>Material Costs</th>
<th>Fuel &amp; Power Costs</th>
<th>Annual Running Cost</th>
<th>Annual Operating Hrs (est.)</th>
<th>Running Cost/ Hour</th>
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</thead>
<tbody>
<tr>
<td>Container</td>
<td>52,500</td>
<td>2,315</td>
<td>44,967</td>
<td>99,782</td>
<td>3,500</td>
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<tr>
<td>Rubber-tyred GC</td>
<td>41,000</td>
<td>237</td>
<td>13,312</td>
<td>54,549</td>
<td>2,000</td>
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<tr>
<td>Straddle Carrier</td>
<td>41,000</td>
<td>90</td>
<td>3,734</td>
<td>44,822</td>
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<td>Front-end Loader</td>
<td>25,000</td>
<td>314</td>
<td>4,709</td>
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<td>1,500</td>
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<td>3,982</td>
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<td>Forklift Truck</td>
<td>18,000</td>
<td>346</td>
<td>960</td>
<td>19,306</td>
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</table>
Responsibility does not, of course, stop with the individual equipment operator. Operations supervisors and managers must bear the responsibility of their subordinates.

Statistical operating information is required for sound maintenance scheduling and fleet planning. Many ports have inadequate systems of recording equipment operating and performance data. Required information includes:

- Daily records of demand for equipment.
- Daily records of equipment available and equipment operating hours.
- Daily records of equipment productivity.
- Records of fuel, lubricants, and other consumables consumption.

Clear definitions of each of these data are required. For instance, operating hours must be defined so that it is clear whether idle time is included. Individual ports have various sources of accumulating operating time, including the following:

- Equipment requisitions.
- Machine working hours from equipment shift logs.
- Engine hour meters recording time equipment is working under load.

A combination of the last two sources is recommended. Hour meters give a good indication of equipment working time. Shift logs can provide a good record of idle time and delays. Whichever source is utilized, it is important that personnel utilizing the data understand the source and limitations of the data.

Allocation, or shift equipment assignment, methods also vary from port to port. The less effective methods allocate equipment on the basis of the operator's requisition for full shift assignment, with no identification of the work to be done.

The recommended method requires the operator to specify the type of cargo, the units of cargo to be handled, and the time of the shift during which the cargo will be handled. Standard production rates divided into the units per hour to be handled, modified if necessary for operating constraints, will indicate the number of units which are required. This method improves equipment utilization and reduces the size of the fleet required, since it minimizes the time that equipment is idle at the berth.

Efficient terminals have developed excellent procedures for forecasting equipment demand. In many cases operators can now plan their equipment requirements, specifying the shift and time within the shift, as much as a
month in advance. Equipment allocation plans, in that detail, can allow excellent maintenance schedule planning, with an attendant increase in equipment availability and reduction of maintenance costs.

12.2 Master Operating Plan

The master operating plan covers a future period of time, usually one year. The plan reflects a forecast of operating and maintenance factors, starting with the volume of cargo units to be handled. This can be worked back into forecasted operating time required for the various units of equipment. Refer to Figure 12.2.1 for a sample format for a chassis based container terminal. Based on the master plan maintenance forecasts can be prepared. This subject will be discussed further in section 13.3, Budgeting.

From this forecast it is possible to prepare a master maintenance schedule which will identify tentative timing on major overhaul, painting, inspection projects which will require extended equipment shutdown. It will also indicate the amount of equipment down time which will be required for each type of equipment. This master plan is prepared jointly between operations and maintenance personnel.

The master maintenance schedule can form the basis of the formal communications required between operations and maintenance management staff. However, refinements to the schedule will be required on a week to week and daily basis, as conditions change, to ensure that plans remain realistic as conditions change. Such adjustments require continual communications between the operating and maintenance departments. As a policy, we recommend a series of meetings to facilitate the necessary communication. The meetings should have a degree of formality in that they should occur on a regular schedule, and not on an "ad hoc as needed" basis. If they are not regularly scheduled, people will become too busy to attend a meeting.

Even when regularly scheduled, there is a risk that people will find reasons not to attend. Management must ensure that this does not happen. Those leading the meetings should restrict the discussions to the intended subjects and avoid long extended meetings because people are busy. The following series of meetings have been found to be effective.

12.3 Superintendent's Forecast Meeting

Frequency: Weekly. (Preferably early during the week at a regularly fixed time)

Scope: Entire port.

Objective:
1. Preparation of a 4 week rolling forecast of production and maintenance requirements.
2. Review the previous week's performance against the plan.
3. Review high priority items requiring action.
This meeting should identify production equipment operating requirements and maintenance requirements for each area of the port for each of the next four weeks. Production equipment requirements may vary from the master plan as a result of shippers plans or other unusual circumstances.

Additionally, we suggest that the previous week's production and maintenance plan be reviewed for compliance and results. This review is important and represents a formal assessment of the quality of scheduling being accomplished at the supervisor's level. Non-compliance with scheduled maintenance activities must be carefully evaluated and controlled. Cancellation of scheduled maintenance may, on occasion, be justified. However, this decision must not be made lightly and should be made at a relatively high level in the organization. We emphasize that the key to achieving maximum production at minimum cost is to accomplish equipment maintenance on a predictable scheduled basis, such that when the operations department requires the equipment, it will operate properly.

Any problems which arose during the prior week should be discussed. High priority work items which might alter future weeks schedule should be considered. The meeting should be attended by superintendent level people as well as planning personnel from both the operations and maintenance departments. The maintenance superintendent should chair the meeting to ensure that the focus remains on maintenance related matters.
### Hypothetical Port - Master Operating Plan

#### Container Terminal

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<tr>
<th>Line No.</th>
<th>Item</th>
<th>1</th>
<th>2</th>
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<th>9</th>
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</table>

**WORLD BANK**
12.4 Weekly Maintenance/Operations Plan Meeting

Frequency: Weekly (Late in the week at a regularly fixed time.)
Scope: Each maintenance area.
Objective: Preparation of the following week's production and maintenance plan.

For each area of the port a separate meeting should be held by each maintenance supervisor. It should be attended by the production supervisors in that area of responsibility, the appropriate maintenance planner, and the operations scheduler. The maintenance manager's forecast for the week will form the starting point for the meeting.

During the meeting a relatively detailed schedule of operations usage and maintenance work on equipment will be finalized. Specific maintenance services and backlogged work planned should be identified for accomplishment during the next week.

Operations supervisors can communicate their priorities and their updated equipment requirements. Maintenance manpower leveling should be accomplished.

As in the case of the superintendent's meeting, but in more detail, specific problems requiring operations and maintenance input should be discussed and, if possible, resolved.

12.5 Daily Scheduling Meeting

Frequency: Daily (Later half of the shift)
Scope: Each maintenance area.
Objective: Establish the next day's work schedules.

The daily scheduling meeting is actually a series of quick but formal meetings each afternoon where each planner receives final priority input and accomplishes final coordination between operations and maintenance staff. Normally, a brief discussion of five to fifteen minutes with the area maintenance supervisor and an operations representative will serve to finalize the next day's work schedule for each maintenance crew.

12.6 Morning Meeting

Frequency: Daily (Prior to the start of the shift)
Scope: Each maintenance area.
Objective: Establish last minute changes to the day's schedule.
A brief meeting should be held just prior to the start of the shift in each area. The area maintenance supervisor runs the meeting and receives input on problems occurring during the previous shifts from the operations supervisor and maintenance personnel. Any necessary changes to the shift work schedules would be made at that time. This meeting should not exceed approximately five minutes.

Throughout all of these meetings, it is essential that both maintenance and operations personnel are willing to adjust their own plans to accommodate the needs of the other when necessary to achieve the broader objectives of the port. There must be an attitude of give and take. If the maintenance department is continually expected to "give", the maintenance program will not be effective.
13.0 MANAGEMENT OF MAINTENANCE COSTS

It is expected that any port will, as a matter of policy, strive to minimize the costs of maintaining equipment and facilities; provided, however, that in the process the other objectives of maintenance and the port are met. The equipment and facilities must have adequate demand availability and maintenance efficiency. The facilities must be protected from abnormal deterioration. Therefore, costs and maintenance performance must be controlled coincidentally. Maintenance costs cannot be controlled without consideration for the impact on equipment performance. It follows that maintenance costs can only be controlled by the maintenance personnel; craftsmen, supervisors, staff, and management.

13.1 Accounting and Maintenance

One aspect of controlling costs is to know how much cost has actually been incurred and what is the make up of those costs. That is to say how much of the cost is:

- Labor.
- Materials.
- Purchased services.
- Maintenance department overhead.

How much are the actual costs for:

- Each work order.
- Each unit of equipment.
- Components.

What are the costs per unit of work?

Most of this information is required quickly. For instance, it should be possible to learn the actual cost status of any open work order on a daily basis. Without quick turn around of cost information, the maintenance supervisor cannot use the information to influence the usage of physical resources which determine costs. It will not be in sufficient time that he can recognize problems and take corrective action.

While accounting departments are normally charged with the responsibility of reporting actual costs, it is the rare accounting system which can report cost information quickly enough for daily use by the maintenance supervisor. Therefore, it is strongly recommended that the maintenance management system provide daily cost information. The maintenance management system costs need not be 100% accurate. If they are within 90% or 95%, the information will be adequate for the maintenance supervisor's control.
The accounting system will still produce the overall cost figures for the port. Maintenance and accounting personnel should cooperate to ensure that duplication of effort is minimized and that accuracy levels in both sets of costs are adequate.

13.2 Cost Control

Costs are controlled through control of physical resources and activities. Work performance is directly controlled by the supervisor. Costs follow directly from this performance, (4.2). Please note that maintenance costs, to some extent, are controlled by equipment operations performance.

Therefore, maintenance costs must be controlled by the same people who are controlling the physical activities, i.e. maintenance department personnel. A controller "approving" purchase requisitions, a warehouse supervisor "approving" stores issues, a port director "approving" overtime work does not control costs. These people cannot know enough details about the situation and conditions which require the expenditure to make informed choices. Furthermore, these are not the people who will be accountable for maintenance results. The result of these type of "external" approvals will be delays in completion of work and, therefore, reduced equipment performance and higher costs.

Control of costs and physical performance must be with the people who are charged with the responsibility of performing the work. These are the people who will know the detailed circumstances and, therefore, will be in a position to make informed choices. They should be given authority which is commensurate with the accountability and responsibility which has been assigned to them.

Senior port management exercises its control in three ways. The most important is through calling maintenance management to answer for results as indicated by the performance measures which have been assigned and especially for deviations in those results from previously approved plans. They must ensure that maintenance management has the necessary skills, tools, training and motivation.

The second is through influencing and approving the maintenance department plans and budgets.

The third is through a system of approving those relatively few physical actions which exceed the authority which has been assigned to the maintenance manager. Clearly, every department head must have limits to the size and type of individual expenditures which he can commit on his own. If, for instance, overhaul of a unit of equipment is going to cost 90% of the cost of purchasing a new unit, senior port management should review the maintenance department recommendation for there may be some factors known to senior port management which would dictate the appropriate course. Most organizations reserve expenditures for capital equipment to the authority of the port director and/or the board of directors.
Each port must meticulously establish the limits of authority which will apply to each department head, including the manager of the maintenance department. The maintenance manager, in turn, delegates portions of this authority, within specified limits.

It is not suggested that the maintenance department be given a free hand in making spending decisions. Actions which the maintenance manager has authority for should be within the scope of a plan and budget which have been justified to senior port management and approved by them. If the maintenance manager needs to initiate actions which go beyond the approved budget, he must go back to senior management for approval of a revised budget.

Avoid the "series of approvals" concept in paper processing procedures. If a purchase requisition must be "approved" for correct accounting code by the accounting department and for correct part number by the materials department, a source of undue delays has been introduced. Systems should be established so that the person originating the requisition will be able to and be expected to correctly indicate this type of information at the time of originating the requisition.

13.3 Budgeting

Budgets should simply be an expression of a plan in monetary and physical units. A budget should represent a condition which can reasonably be expected to happen.

Consequently, budgeting should begin with an overall port plan. The plan should be prepared in detail for at least a one year period. Detail should be shown for each month, or accounting period if different from a month.

A port should also have a longer range plan. A five year span is often used. The long range plan will have less detail but will present a broad picture of what the port expects to achieve over the time frame.

The discussion here will center on the one year plan and budget. For this purpose we will not distinguish between plan and budget, using the two words synonymously. The port operating plan, as discussed in section 10.2, Master Operating Plan, applying equipment utilization factors, will display the following types of information:

- The number and type of ship operations.

- The amount of cargo units to be handled, detailed by each type of cargo unit and the type of handling operation.

- The amount of operating hours for each type of equipment.

Based on the port Master Operating Plan, the maintenance department will, by applying standard service factors, be able to develop a maintenance plan. This will include, for each week in the year:
- The demand availability and maintenance efficiency expected for each type of equipment.
- The hours which each type of equipment is expected to be down for preventive and predictive maintenance.
- The hours which each type of equipment is expected to be down for corrective (or repair) maintenance.
- The hours which each type of equipment is expected to be down for major overhaul, major painting, etc.
- Modification or capital addition projects which will be performed by the maintenance department.
- The maintenance manpower required, for the work indicated above, detailed by craft.
- An estimate of the cost of materials required for the work indicated above.
- The maintenance supervision and staff required, detailed by position.
- An estimate of the cost of maintenance department labor.
- Identification of outside resources required for specialized services.
- An estimate of the cost of outside maintenance contractor services required.
- Calculation of all of the performance measure indices which will be applied to each position.
- Identification of maintenance department equipment which is to be replaced, identifying the functional specification of the new equipment to be purchased and estimated cost.

Plans and budgets are prepared with the input from all departments and a specific sequence is usually required. Most often the plan begins with the commercial department forecasting the cargo volumes which can be expected. Then the operations department forecasts the equipment operating hours required. Then the maintenance department estimates its resource requirements.

Maintenance should also have a voice along with operations, engineering and business development in development of the overall port capital equipment budget.

At the beginning of the process, senior port management should establish the broad goals which should be incorporated into the plan. Of special importance are any goals which will have a significant impact on operations.
If, for instance, it is planned to expand container throughput, this should be clearly identified so that each department can rationally forecast the impact that this will have on them.

At appropriate steps through the budgeting process, the forecasts and recommendations developed by each department are reviewed by senior management. Senior management, in this way, has the opportunity to influence and "control" the maintenance operations. There is usually a great deal of dialogue between the department and senior management in questioning and justifying plans and budgets.

One difficulty which many organizations have with budgets is the difficulty in coping with change. The problem is that often actual conditions may be significantly different from those which were anticipated when the budget was prepared. Most common is a significant deviation in the volume of cargo to be handled.

A useful technique for dealing with this problem is the use of a flexible budget. In this approach an annual budget is prepared, as described above. Major budget determiners are identified. For example the number of container moves would be a determiner of the operating hours required of a container crane. In turn crane operating hours will be a determiner of the amount of maintenance work required. Certain costs may be fixed in nature. The budget determiner for those will be the passage of time. Therefore, they are not expected to deviate from the original budget. As the year progresses actual quantities of each determiner are used to recalculate the budgets against which performance is measured.

The flexible budget provides a means for each department manager to engage additional resources when the port is busier than originally expected. Conversely it puts pressure on the department head to reduce costs when port throughput, and, therefore, revenue are less than expected. It automatically directs the financial pressures of the port to the people who control costs.

It is, of course, the responsibility of the Business Development Manager to advise maintenance and operations of impending volume changes as early as known.

Preparation of budgets involves large quantities of calculations. A personal computer utilizing "spreadsheet" software is a great aide in preparing budgets. The maintenance department should have these at their disposal.

A plan and budget which has been developed with the flexible budget concepts and which is built on a PC spreadsheet, can be used by senior management for financial planning; evaluating the effect of variations in cargo volumes, price changes, capital equipment changes, financing sources, etc.
13.4 Foreign Exchange Needs Forecasting

Since, in many nations, supplies of foreign exchange are limited, and these limitations can have a serious impact on port maintenance activities, special attention must be given to foreign exchange in managing maintenance costs. The primary tool is the budget preparation. During development of all aspects of the budget, the foreign exchange generated or required must be detailed separately from local currency. In that way senior port management will know how much foreign exchange will be generated by the port and how much will be required to maintain and operate the facilities. It is their job to ensure that sufficient foreign exchange is available to meet the port's needs.

As discussed in Para 4.3, where foreign exchange is very scarce, the port should prepare a detailed budget of its foreign exchange requirements for the ensuing year covering essential needs only such as spare parts, materials, and specialist technical assistance for the maintenance tasks. The government should allow the port to retain part of its foreign exchange earnings to at least equal this essential budget. At the end of the year the port can submit a report showing how the funds were in fact disbursed. Unless action such as this is undertaken, maintenance will never be carried out efficiently and the port's performance will be seriously affected.

Where foreign exchange is less scarce but still restricted and based on information from the central bank, or finance ministry, senior port management must determine if there will be a sufficient foreign exchange allocation to meet the port's needs. If a shortfall is anticipated, plans must be made to focus the limited funds to uses where they can accomplish the most. The funds should not be diluted by "spreading them around to all uses" and failing to accomplish any of the intended results. Care must be exercised in establishing these priorities. Uses which can be accommodated with local funds, even though less efficiently, should receive low priority ranking for purposes of foreign exchange allocation.
14.0 THE USE OF OUTSIDE TECHNICAL AND MANAGEMENT CONSULTANTS

No port can have all of the technical and management know-how, that may be required from time-to-time, within its own organization. If, for instance, a port attempts to retain on its payroll all of the engineering staff which would be required to design and manage a major port expansion project they would have excessive engineers and costs during those periods in which there was no major project going on. Even if the port concluded that it would be advantageous to carry such staff during periods of little activity, there are some other risks. Staff would find a lack of challenge during the slow periods and the better people would find other opportunities with other employers. The mediocre people would stay, leaving the port with a mediocre engineering department.

The other risks is that an under-utilized staff, during slow periods, will generate work to be done, much of which could not be economically justified. The port will end up spending money which is not really necessary.

Therefore, the port will need a specific policy governing the procurement of Outside Technical and Management Assistance.

In determining the amount of technical know-how, which is to be retained in the port's permanent staff, a base load of work should be defined. The base load represents a level of work which can be expected to recur month after month in the periods of low activity as well as high activity. The objective should be to employ staff which have the ability to perform this work. Technical know-how which is required for the peaks above the base load should be contracted from outside sources when needed.

Of course, if it is not possible to hire people with the specific know-how required for portions of the base load work, it may be necessary to use outside sources for that work also.

The ability to procure and manage outside assistance is unique. Ports are well advised to select an outside consultant, with whom they can develop an ongoing arrangement, who will help prepare specifications for technical and managerial projects and assist with the project evaluation, procurement, and monitoring of the work.

Technical Assistance falls generally into two categories. Technical consulting deals with engineering matters. Management consulting deals with organizational, systems, procedures, training, control, and other management matters.

The technical and management assistance components of projects tends to be of too short a duration. Some situations may require continuing technical assistance for periods of five years and even longer, to ensure that the technology transfer has taken place. Planning of projects should include an assessment of the port's maintenance capability and include the necessary technical assistance in the project. Outside assistance requirements should be defined in very specific terms, so that the appropriate assistance is
14.1 Contractual Arrangements For Outside Consultants (OTC)

Scope of Work

It is essential, before engaging an (OTC), that the work to be done is specified. The more clearly port management can describe the scope of the OTC's work the more successful will be the contract. If the OTC has a different impression than port management of the work to be done, the port will, almost certainly, not be satisfied with the OTC's services. It is worth spending the necessary effort to develop a good task specification.

In some cases, port management may only know the symptoms of a problem, without understanding the fundamental problem. It is not wise to engage an OTC to solve a problem which is not yet defined. In such cases a consultant may be engaged to identify the problem and recommend a solution. Once that solution has been identified, port management must decide, whether they will implement the solution with port staff, utilize that same consultant, or engage another OTC. This type of work should be assigned to an OTC in which the port has a high degree of confidence. This is one reason for having an ongoing arrangement with an OTC, as referred to on the previous page.

In other cases the port may have the staff necessary to manage certain work, but insufficient staff to perform it. Secondment of personnel to fill the vacancy for a temporary period of time should be considered. Secondment implies that the OTC's person will take day-to-day supervision from port personnel. The OTC's person effectively functions as a port employee.

Compensation

The method of compensating an OTC is particularly important. There are three basic methods which are most commonly used. They are:

- Fixed price. This is often called the lump sum method. In this method the OTC is paid a predetermined amount of money for the specified task. This method should only be used when the scope of work is very well defined. The risk in this method is that it may give the OTC an incentive to do less work than is actually required. Therefore, if the work cannot be well specified this method should not be used.

- Time and Materials. In this method the OTC is paid a predetermined price for each unit of time worked plus reimbursement of costs for materials used, travel expenses, etc. This method has the advantage that the amount of work performed can be flexible if the scope of work cannot be well defined at the outset. It has the disadvantage that costs of the service may exceed the amount originally expected if the OTC spend more time than expected. To minimize this risk the OTC should estimate the costs for the job. If subsequently he finds it necessary to spend additional time, he should receive approval from the port prior to
proceeding with the extra work.

- **Cost Reimbursement Plus a Fee.** In this method the OTC is reimbursed for his actual cost and in addition paid a predetermined fee. This has the disadvantage of being a more complex contract to administer, since the port must become satisfied as to the OTC's "actual costs". Therefore, this approach will normally be applied only to "larger complex contracts".

14.2 **Selecting the Outside Consultants**

It is recommended that the port utilize the "Guidelines for the Use of Consultants by World Bank Borrowers and by The World Bank as Executing Agency", regardless of how the task may be financed. This booklet is available from the World Bank at no charge.