Improving Equipment Management in Highway Authorities in Developing Countries

Clell G. Harral and James W. Eaton

July 1986

This is a document published informally by the World Bank. The views and interpretations herein are those of the authors and should not be attributed to the World Bank, to its affiliated organizations, or to any individual acting on their behalf.
IMPROVING EQUIPMENT MANAGEMENT IN HIGHWAY AUTHORITIES IN DEVELOPING COUNTRIES

by

Clell G. Harral
Transport Policy Adviser
World Bank

and

James W. Eaton
Head, Mechanical Consultancy
Crown Agents

July 1986

Transportation Department
Operations Policy Staff
The World Bank
The efficiency of equipment management and usage is very low in many parts of the developing world. This is typically manifested in low equipment availability and utilization, causing severe economic losses. The deficiencies can generally be grouped under three problem headings, namely, managerial and general organization, spare parts, and foreign-aid induced problems. The first of these tends to be endemic in most road organizations in developing countries. The second problem is frequently the direct reason for the low availability of equipment. And the third problem has to do with proliferation of equipment makes, and excessive new equipment purchases, which respectively add to and are induced by the spare parts problem.

This paper gives recommendations on how to reduce, and hopefully go a long way towards eliminating the problem. The first step obviously is to take stock of equipment at hand and its condition, as well as workshops, stores, manpower and management. Following this, further actions and needs are defined. Such actions would include improvements in management systems, e.g., equipment monitoring, spare parts supply and control systems, and cost accounting, to name but a few. They may evolve into plant hire schemes, or into increased use of private or parastatal contractors, either for the road maintenance function itself, or of the equipment provision, maintenance, spares provision or some portion thereof. Finally, systems and criteria for decision-making on equipment acquisition have to be set up in conformity with principles of sound financial management.
Improving Equipment Management
in Highway Authorities in Developing Countries

CONTENTS

Chapter

I Summary, Conclusions & Recommendations ........................................ 1

A. The Problem ......................................................................................... 1
B. Causes of Inefficiencies ....................................................................... 3
C. Recommendations ................................................................................ 5

1. Increased Attention to Equipment Efficiency ..................................... 5
2. Increased Utilization of Contractors .................................................. 7
3. Improvements in Management Systems ............................................. 7
4. Plant Hire Schemes ............................................................................ 8
5. Financing ............................................................................................. 10
6. Aid Coordination ................................................................................ 11

II Monitoring Performance and Costs .................................................... 12

A. The Problem: Some Evidence on Equipment Availability
   and Utilization .................................................................................... 12
B. Management Information Systems ...................................................... 14
C. Monitoring Indices: Crown Agent's Information
   System (Stage 1) ................................................................................ 15

III Spare Parts Supply Systems & Management ....................................... 20

A. Introduction ......................................................................................... 20
B. Systemic Problems in Spare Parts Supply ........................................ 21
C. Elements of an Effective Spares Supply System ................................ 22
D. Conclusions ......................................................................................... 23

IV Life-Cycle Costing and Fleet Replacement Policies ............................... 25

A. Introduction: Economic Costs and Equipment Decisions ................. 25
B. Prediction of Life-Cycle Costs .............................................................. 25
C. Optimum Economic Life of Equipment ............................................. 29
D. Fleet Rationalization/Standardization ................................................. 34
   1. Quantifying the Benefits of Fleet Rationalization/
      Standardization ............................................................................... 35
   2. Tender Evaluation .......................................................................... 38
Chapter

V Cost Accountability, Hire Schemes and Funding .................. 40

A. Deficiencies in Current Practices ............................. 40
B. Plant Hire Schemes ........................................... 41

1. Objectives ..................................................... 41
2. Costing and Pricing ........................................... 42
3. Budgeting and Funding ........................................ 42

VI Equipment Management Improvement Plans ..................... 46

A. Introduction ................................................... 46
B. Scope .......................................................... 47
C. Equipment Fleet Holdings, Utilization and Management .... 48
D. Fleet Size, Suitability and Replacement Policies ............ 50
E. Equipment Maintenance ....................................... 51
F. Supplies and Spare Parts ...................................... 52
G. Finance and Administration ................................... 53
H. Staffing ........................................................ 54

BIBLIOGRAPHY ...................................................... 56

ANNEX 2.1 Definition of Terms .................................... 57
ANNEX 2.2 Stage I - Management Information Reports and Worksheets 58
ANNEX 6.1 Terms of Reference: Preparation of Equipment Management Improvement Plans 67
IMPROVING EQUIPMENT MANAGEMENT IN HIGHWAY AUTHORITIES IN DEVELOPING COUNTRIES

I. Summary, Conclusions and Recommendations

A. The Problem

1.01 Equipment availability and utilization\(^1\) in most road authorities in developing countries are thought to be extremely low, very possibly only about one-fourth to one-third reasonable norms. "Thought to be" because available evidence is fragmentary or of questionable validity. The evidence that is available suggests that while availability may be good during the first one or two years of the life of new equipment, thereafter availability typically declines sharply, as machines begin to wear, and maintenance is inadequate due to non-availability of spare parts or lack of properly trained mechanics. Utilization may be poor even during the first years, and, since it is dependent on availability, utilization is necessarily poor during subsequent years.

1.02 Economic losses entailed in such inefficiencies are of a large order of magnitude. At a minimum they imply investment in a fleet much larger than that which would have been necessary to achieve the given work program; if such excess investment in equipment is not made, and the road maintenance simply does not get done, the consequential losses, e.g., in deteriorating roads and increased road user costs, are of an even larger magnitude. Table 1.1 shows the costs of equipment ownership (i.e., capital and interest) for various sizes of fleet and the minimum economic losses due to excess investment requirements compared to an efficient utilization of 1250 hours per year.\(^2\) Where utilization is only 250-500 hours per year, as is often the case, minimum economic losses may range from about $5 to $15 million or more per annum for a relatively small country (with basic

---

\(^1\) In keeping with standard usage the term "availability" is used to denote the total hours in a given time period that the machine is operable, either working or available for work. "Utilization" is the time the machine is actually worked. Availability and utilization are commonly expressed as percentages, but since the base may vary widely and is often unknown, the usage of percentages is best avoided. If percentages are used, it is essential that their base be given.

\(^2\) Not all items of equipment can be expected to achieve 1250 hours p.a., especially specialized items (e.g., cranes) which are required only sporadically in the production process but yet must be kept available for the brief periods when they are required. Major items of plant and vehicles, constituting the bulk of the investment, should, however, be capable of achieving this target, and even higher under favorable conditions.
# Table 1.1

**The Costs of Equipment Ownership and Economic Losses Due to Inefficient Utilization**

## A. Capital and Interest Costs by Size of Fleet

<table>
<thead>
<tr>
<th>Size of Fleet (US$ million)</th>
<th>Initial Capital Cost</th>
<th>Interest - 8 years @ 12%</th>
<th>Total ownership costs - 8 years</th>
<th>Ownership costs per year</th>
</tr>
</thead>
<tbody>
<tr>
<td>20</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>50</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>100</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>200</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

1/ Assuming straightline depreciation, principal is on average one-half of initial capital cost.

## B. Annual Economic Loss due to Excess Equipment Requirements

<table>
<thead>
<tr>
<th>Annual Utilization (Hours)</th>
<th>Relative Fleet Size Required</th>
<th>Annual Economic Loss</th>
</tr>
</thead>
<tbody>
<tr>
<td>1250</td>
<td>1</td>
<td>-</td>
</tr>
<tr>
<td>1000</td>
<td>1.25</td>
<td>0.93</td>
</tr>
<tr>
<td>750</td>
<td>2.67</td>
<td>2.48</td>
</tr>
<tr>
<td>500</td>
<td>2.50</td>
<td>5.55</td>
</tr>
<tr>
<td>250</td>
<td>5.00</td>
<td>14.80</td>
</tr>
</tbody>
</table>

2/ Assuming basic fleet requirements on 1250 hours utilization, with lower utilization requiring correspondingly larger fleet size with same economic life.
fleet requirements of only $20 million) to as much as $50 to $150 million per annum for a larger country with basic fleet requirements of the order of $200 million. The fleet investment of road authorities in larger, more developed countries such as Nigeria, Brazil and Argentina would be of still larger magnitudes; a recent World Bank study in Turkey estimated the replacement value of the KGM road authority's 18,000 item fleet at approximately $550 million.

1.03 The importance of improving utilization of existing fleets can be appreciated when it is recognized that annual economic losses from inefficient utilization will often equal or exceed entire World Bank lending for roads to the countries concerned. Moreover, significant gains in efficiency may often be effected with nil investment by changes in operating practices, or by modest investments, e.g., in adequate inventories of spare parts. Thus, improvements in efficiency of utilization of existing fleets should become a prime objective of future World Bank activities in the roads sector, and any future lending for equipment should be predicated upon a detailed Equipment Management Improvement Plan with specifically identified measures and targets for efficiency improvements, as discussed below.

B. Causes of Inefficiencies

1.04 The multifarious causes of inefficiencies in equipment utilization can be grouped under three heads: (i) general organizational and managerial problems; (ii) foreign-aid induced problems; and (iii) the spare parts problem. In the first category are the problems which tend to be endemic to most government agencies in all countries, and which often severely afflict road authorities in developing countries:

(a) Difficulties in attracting, developing, and retaining able staff (in management, in the workshops and perhaps most critically in spares supply and stock control), due primarily to salary differentials with the private sector;

(b) Absence of compelling incentives for efficiency in the public roads authority, which normally enjoys a monopoly (at least for maintenance services) fostering a general lack of costs consciousness and concern;

(c) Weaknesses in management information systems including, typically, inaccuracies, much irrelevant detail, yet lack of critical information on a timely basis, and a general tendency to overlook or understate costs.

1.05 Foreign aid from different sources has at times aggravated indigenous weaknesses:
(a) By making too much money available for new equipment, thereby diminishing incentives for better maintenance and utilization of existing fleets; and

(b) By proliferating different makes and models of equipment, thus compounding spares support and servicing problems.

The latter issue, proliferation, is a particularly serious problem in many of the smaller, poorer countries. Not being in a position to refuse aid from any source, they typically end up with fleets of many different makes and models with the number of each item well below the minimum fleet size at which it is economic to maintain separate stocks of spares and tools and to train mechanics. This is often due to the fact that aid is 'tied' to procurement in the country of the donor, and there are many donors. But it may also result from internal procurement procedures which require selection of the item with the lowest tender price, regardless of the subsequent costs for spares stocking and support services.

1.06 The spare parts problem is commonly considered the most important cause of inefficient utilization of equipment, for if the 'right spare part is not available at the right place at the right time' then equipment is inevitably kept unserviceable for long periods of time 'awaiting spares', an ubiquitous phenomenon in nearly all road authorities. Yet, seemingly paradoxically, in the same agencies there are typically large stocks of redundant spares. Optimal policies, of course, involve balancing the costs of equipment downtime against the costs of additional inventories of spares. Since the costs of equipment awaiting spares is normally of a much larger magnitude than the costs of additional spares inventories, some substantial redundancies in spares provision are desirable, unless lead times to replenish stockouts can be made very short.

1.07 While the basic principles are obvious enough, there are many obstacles to achieving optimal spares supplies:

(a) Technical difficulties in forecasting precise needs. The equipment manufacturers' recommendations, even where their intentions to help the purchaser (rather than simply offloading their own redundant stocks) can be trusted, are often of limited value because local conditions (e.g., skills level of operators and mechanics, physical working conditions and specific work tasks) can vary widely. Specific data from local spares usage accumulated over time are needed for accurate predictions, and this type of datum is normally not available from existing information systems.

(b) Excessive proliferation of different makes, models and ages of equipment, which multiply spares requirements. This is due not only to the reasons discussed in para 1.05 above, but also to the presence of overaged items resulting from the combination of financial pressures and failure to apprehend the exceptionally heavy costs associated with keeping overaged equipment in service. Particularly where numbers are reduced to only a few
pieces of a given type, the costs of maintaining spares stocks alone may exceed the benefits of keeping the item serviceable, yet cumbersome government procedures discourage disposing of non-economic equipment.

(c) Deficiencies in stock control, warehousing and distribution. The supplies function to a government roads department is typically a large scale, complex operation, yet seldom are modern management techniques for inventory control and logistics employed. Problems are at the most basic level: inventories are not kept up-to-date, items are not properly labelled or shelved and stock control records are inadequate to locate items already in stock, let alone provide a proper basis for prediction of future requirements. It is difficult to dispose of outmoded items so that they accumulate over time; in fact, several cases are known where the accretion of outmoded spares over time has left no shelf space so that the more recently acquired, and urgently needed, spares are left inaccessible in shipping crates, or worse, expose to the elements, misplacement and pilferage.

(d) Cumbersome, inappropriate procurement procedures which cause delays and other problems. Low financial ceilings on procurement authorities for even senior management and requirements for multiple handling by different offices of government (e.g., departmental tender boards, central tender boards, treasury, etc.) virtually ensure delays in issuing purchase orders; they are also susceptible to the very malpractices which they are intended to prevent, since any individual may hold up even a large procurement until he is given sufficient incentive to clear it. Further delays may be encountered when suppliers insist on cash payment in advance because of government's known tardiness in settling its accounts. Where spares are procured under competitive tenders, inadequate attention may be given to quality specifications and cheaply-priced, but poor-quality items obtained.

(e) Budgetary restraints on recurrent accounts and shortages of foreign exchange which restrict the amount invested in spares inventories. However, it should be noted that there are instances where investments in spares inventories have exceeded any conceivable need, and it must be emphasized that additional finance by itself is rarely, if ever, sufficient to solve the spare parts problem.

C. Recommendations

1. Increased Attention to Equipment Efficiency in Project Preparation

1.08 Much more attention should be given during project preparation an subsequently during implementation to the level of availability and efficiency of utilization of the existing equipment fleet held by the government
roads authority, and to measures for improvement therein. This would begin
with systematic, comprehensive analysis of existing and likely future con-
straints on availability and utilization, including:

(a) A comprehensive inventory and evaluation of the condition of the
existing fleet, identifying that equipment which is still service-
able, that which can be rehabilitated and that which should be
scrapped;

(b) A thorough examination of the entire supply system, including
procedures for identification of requirements, financing,
procurement, stock levels and control systems, warehousing,
distribution and disposal of outmoded stocks;

(c) An assessment of the adequacy of workshops, tools and equipment,
including mobile workshops;

(d) An assessment of human resource requirements, availabilities and
measures to fill the gap. The requirements for equipment
operators and mechanics are obvious, and typically training
programs have concentrated on these needs, but critical needs in
supplies management and stock control have often been overlooked;
and

(e) An evaluation of the structure and level of incentives (both posi-
tive and negative) for all staff from operators, mechanics and
stockmen through top management. In many instances there are
strong incentives operating against efficiency, and unless these
can be reversed there is little prospect for improvement.

1.09 A realistic program, taking into account these constraints but
also encompassing measures to alleviate them, should then be prepared to
meet future needs. This would include:

(a) An assessment of the prospects for contracting out certain
functions rather than establishing or maintaining departmental
(force account) capabilities (see 1.10 - 1.12 below).

(b) Identification of needed improvements in management systems for
the remaining public sector (para 1.13), including

(i) Development of a plant-hire scheme or other measures to im-
prove cost accounting and regularize financing of spares pro-
curement and equipment replacement (paras 1.14 - 1.17); and

(ii) Development of an Equipment Management Improvement Plan
(EMIP) as discussed below (Chapter VI of the main report):

(c) Coordination among foreign aid agencies (paras. 1.19-1.22).
2. Increased Utilization of Private or Para-Statal Contractors

1.10 Considering the various constraints operating on the government service, as well as its existing assets, an assessment should be made of the possible role of the private sector where the prospect exists that certain portions of the responsibilities of the road authority could be contracted more economically than establishing or maintaining direct governmental (force account) services. This may encompass the road maintenance function itself, or the equipment provision, maintenance, spares stocking and supply, or some portion thereof. Another approach could involve a management services contract (preferably on an incentives basis toward target service levels) to manage government-owned fleets or spares inventories, thus overcoming critical government constraints on staffing and incentives. Where there are already established manufacturer's agents, it may be that the provision of spares and major repairs of equipment can be handled most efficiently by the agent.

1.11 Such arrangements have broken down in some cases, however, because of the government's tardiness in paying for goods and services delivered, or where the government has restricted access to foreign exchange by the private sector (with preferential access for its own agencies). They have also broken down due to government insistence on large discounts where locally available supplies are restricted (and market prices are much higher), or by governmental unwillingness to give more than a short term contract (1 or 2 years) where a longer term contract (e.g., 5 years, renewable annually) would be required to establish and maintain private investments.

1.12 To involve the private sector effectively will require a genuine and sustained commitment by the government to this approach, and it may require enhancement of government capabilities to supervise contractors. Often, however, the governmental authorities concerned prefer direct control and may resist such an approach. They also may be misguided by government accounting which understates the economic costs of direct government provision of services, e.g., by ignoring capital costs altogether, or omitting interest costs, depreciating assets on historic values rather than replacement costs, failing to write off capital losses in redundant inventories, or understating the overhead costs (at least some, and perhaps many of which, could be avoided were services contracted out). When comparing costs with private suppliers an adjustment would also normally have to be made to net out any corporate income or indirect taxes levied on the private supplier from which the government supplier would be exempt.

3. Improvements in Management Systems

1.13 Improvements in management information and decision systems of the road authorities will normally be required. It should be noted, however, that technical assistance through international management consultancies, which have generally attempted to introduce the most modern, comprehensive

systems de novo, has often failed. Even in the industrial countries such complex, holistic new systems do not always function well, and they can be totally inappropriate to the circumstances of road authorities in Third World countries. A policy of piecemeal improvements to existing systems should always be considered, and any introduction of whole new systems should normally be phased in by stages. The essential elements of a system for effective equipment management include:

(a) Basic statistics monitoring equipment availability and utilization, and providing targets for improved performance, as discussed in Chapter II of the report;

(b) Spare parts supply and control systems as discussed in Chapter III;

(c) Explicit policies and a quantitative base for decision-making concerning equipment life and replacement (including cumulative data on actual maintenance expenditures for each piece of equipment), as discussed in Chapter IV;

(d) Explicit policies and a quantitative base for calculating the benefits of standardizing on specific makes or models (comprising estimated costs for additional spares inventories, mechanics' training, etc. necessary to achieve the same level of service for additional models as for proposed standard models), as discussed in Chapter IV; and

(e) Ultimately, a comprehensive cost accounting system for management (as distinct from purely financial control) purposes, e.g., to compare alternative approaches, such as the costs of internal (force account) operations with the costs of contracting those operations, the costs of equipment-intensive operations with labor-based methods, etc., as discussed in Chapter V below. Volume of this report elaborates one possible management information system which would yield the data base for all the above elements.

4. Plant Hire Schemes

1.14 Historically, and still today in some road authorities, efficient management of equipment fleets has been achieved through operation of departmental plant-hire schemes on a basis similar to a commercial plant-hire organization. The user is charged a hire fee designed to cover the costs of depreciation, preferably at replacement prices and including interest at market rates\(^4\), plus the costs of maintenance of the machine; the equipment operator also may or may not be hired with the machine. Such schemes, when successfully implemented, can achieve important objectives:

\(^4\) Unfortunately, the cost of interest on the capital investment, which would add about 50-60% to depreciation charges, is usually ignored, in keeping with general government practice.
(a) By compelling explicit accounting of costs, they inculcate greater cost consciousness and hence not only generate pressures on the users for efficiency in utilization of expensive plant and vehicles, but also help to curtail excess investment in equipment, e.g., where other approaches, such as labor-based methods, would be more economical;

(b) By making finances of the plant hire organization dependent on revenues generated from plant hirings, strong incentives may be generated to keep plant in operating condition, since broken-down plant generates no revenues; and

(c) When operated as autonomous, self-financing authorities, they can provide for regular replenishment of spare parts and replacement of equipment out of revenues generated from plant hire, thus overcoming serious difficulties stemming from irregular availability of funds for these purposes typically encountered by most road authorities.

1.15 Unfortunately, such plant-hire or hire-funding schemes have generally not worked well in developing countries during recent years, due largely to the failure by the public administration to resist pressures from equipment users (often the road authority itself) to understate equipment costs, ostensibly so as to stretch limited budgets further, and partly to reluctance of Treasury officials to cede financial autonomy, who therefore insist that hire fund revenues be paid into the general exchequer. Consequently, hire rates are typically kept artificially low, funds generated are not nearly adequate to replace outworn equipment (particularly during periods of rapid inflation), funds are not available for timely replacement of equipment, and the true costs of equipment remain hidden.

1.16 It must be recognized, however, that in following such practices the government is understating its costs and actually consuming its capital. Among the consequences are reduced efficiencies (as overaged equipment requires excessive maintenance and is unserviceable much of the time) and the tendency to use more equipment-intensive methods (where labor-based methods would in actuality be cheaper) and to extend governmental direct labor execution to activities which could be done more cheaply by contractors. Government's capital expenditures on plant and vehicles then become larger than optimal, and much of this investment is wasted.

1.17 Where governments have the will to effect the necessary improvements in efficiency, to which proper cost accounting and regular financing of equipment maintenance and renewal have much to contribute, the establishment of effective plant-hire schemes or similar mechanisms should be possible. They are not inherently complex or difficult undertakings; many examples of successful such schemes exist in the private world (although usually on a smaller scale) and in road authorities in several industrial countries today and developing countries in the past.
5. **Financing**

1.18 Improvements in utilization of equipment fleets appear likely to yield the highest economic returns of any investment in the roads sector in most countries today. The investments required are in fact normally quite modest, what is required rather is a conscious and sustained commitment by all levels of government to make the system work for greater efficiency. Where there is no such will, and efforts to evoke it are unsuccessful, the case for Bank involvement in further financing of equipment (indeed, for any further financing in the roads sector) is inherently weak.

1.19 Although there are few hard facts, experience quoted from many sources suggests strongly that finance for new equipment purchase has often been made too easily available from diverse foreign sources, while restrictions in recurrent budgets for spares provision, equipment maintenance and operations have severely afflicted utilization of existing fleets. A facile conduit for both multilateral and bilateral aid, as well as supplier export credits, the eager supply of credit for new equipment is matched by a seemingly unquenchable thirst of road authorities, whose inherent tendencies may be aggravated by circumstances which can make it easier to obtain whole new equipment than the spare parts to maintain existing items.

1.20 To alleviate these fundamental problems, international aid agencies should assist governments to attain a better balance among financing of new equipment, spare parts inventories, and recurrent costs of operation. The sums involved are not large magnitudes relative to the total government budget for the highways sector, and the solution of the problem could largely be effected by the government itself. However, aid agencies need to ensure that their financing policies do not create incentives which distort the government's own priorities.

1.21 In the field of equipment finance this means specifically that the Bank and other aid agencies should:

(a) Be prepared to finance larger provisions for spare parts. These provisions would, however, be procured only in several tranches over the life of the equipment and in response to needs demonstrated through substantially improved inventory control systems;

(b) Establish more selective criteria and procedures for financing of new equipment purchases. New equipment financing should be approved only on the basis of an agreed comprehensive Equipment Management Improvement Plan (Chapter VI), including targeted improvements in utilization of existing fleets, and the measures necessary to achieve these targets. The benefits and costs of standardization would be explicitly quantified wherever possible. Plant-hire schemes on commercial principles (or their equivalent) would be strongly encouraged; and
(c) Adapt technical assistance and training programs to facilitate the above recommendations and increase emphasis on efficient utilization of equipment fleets.

6. **Aid Coordination**

1.22 After agreement with the government, the Equipment Management Improvement Plan should be made available to all prospective donors, and they should be encouraged to coordinate their own equipment assistance therewith. By doing this, it may be possible to reduce problems of proliferation of different makes, discontinuous financing in large, lumpy bunches of new equipment, and inadequate financing of spares.
II. Monitoring Performance and Costs

A. The Problem: Some Evidence on Equipment Availability and Utilization

2.01 Other factors being equal, equipment availability (or serviceability) may be taken as a measure of the effectiveness of the equipment maintenance and spares supply branches, while, for a given availability, utilization may be taken as a measure of the efficiency of the field operation. Other factors which have a major effect on availability and utilization are equipment age, the skill and motivation of operators and mechanics, the physical nature of the field conditions and work being performed, the degree of remoteness of the worksite from support facilities, the balance among different resources available and between the equipment fleet capacity and the amount of work to be performed. Primarily because of the remoteness of operations from support and supervision, road maintenance equipment normally would experience lower availability and utilization than would equipment concentrated at, say, a large construction site with its own workshops and stocks of spares or with close access to similar support facilities.

2.02 Annex 2.1 describes the set of definitions adopted for reporting equipment availability and utilization by the Crown Agents. Availability and utilization are most commonly expressed as percentages of one of several different bases (e.g., total annual working hours, total available hours, available hours less time lost due to climatic factors, etc.). However, where the exact base is not known the use of percentages can be quite misleading, and it is therefore recommended here that all figures be reported in annual hours rather than percentages; if percentages are shown, it is vital that the absolute numbers also be reported.

2.03 Although there is ample anecdotal testimony to infer that equipment availability and utilization are extremely low in many road authorities in developing countries, the available quantitative evidence is fragmentary and offers little basis for systematic analysis. Table 2.1 summarizes evidence from 24 countries in terms of overall percentages for hours available, and in some cases, hours utilized. Unfortunately, the base of these percentages is generally not known; in some cases total time may be taken as 2,000 hours per year (nominally, 50 weeks x 40 hours), but in many cases a lower figure may have been used to allow for holidays, poor climatic conditions or even time down for scheduled preventive maintenance.

2.04 The establishment of reasonable, practicable norms for any given operation is difficult, since all the factors cited at para 2.01 may vary widely. Reference to well-established road authorities operating in developed countries suggests that overall fleet averages for major items of equipment in road maintenance operations may be about 1200-1300 hours per annum under moderate climatic conditions, or 60 percent total utilization of a nominal 2,000 hours working year. If one accepts the figures shown in Table 2.1 — and it is feared that many of the numbers are only rough guesses which may tend to overstate actual performance — only two of the 24 countries reported would appear to be achieving this level of utilization, and at least eight would be achieving only half or less. Given the costs involved, better management information on equipment availability and utilization is a clearly needed first step toward improving performance.
Table 2.1
Equipment Availability and Utilization:
Overall Fleet Averages in Some Road Authorities

<table>
<thead>
<tr>
<th>Country</th>
<th>Year</th>
<th>Age of Equipment</th>
<th>Availability</th>
<th>Net(^1) Utilization</th>
<th>Net(^2) Utilization</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Eastern Africa</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1. Botswana</td>
<td>1982</td>
<td>72</td>
<td>85</td>
<td>61</td>
<td></td>
</tr>
<tr>
<td>2. Ethiopia</td>
<td>1981</td>
<td>59</td>
<td>48</td>
<td>28</td>
<td></td>
</tr>
<tr>
<td>4. Lesotho</td>
<td>1982</td>
<td>75</td>
<td>66</td>
<td>50</td>
<td></td>
</tr>
<tr>
<td>5. Malawi</td>
<td>1981</td>
<td>8</td>
<td>70</td>
<td>80</td>
<td>56</td>
</tr>
<tr>
<td>6. Swaziland</td>
<td>1981</td>
<td>59</td>
<td>75</td>
<td>44</td>
<td></td>
</tr>
<tr>
<td>7. Tanzania</td>
<td>1982</td>
<td>51</td>
<td>73</td>
<td>37</td>
<td></td>
</tr>
<tr>
<td>8. Zimbabwe</td>
<td>1981</td>
<td>74</td>
<td>45</td>
<td>33</td>
<td></td>
</tr>
<tr>
<td><strong>Western Africa</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>9. Cameroon</td>
<td>1982</td>
<td>51</td>
<td>70</td>
<td>36</td>
<td></td>
</tr>
<tr>
<td>10. Gambia</td>
<td>1982</td>
<td>75</td>
<td>69</td>
<td>52</td>
<td></td>
</tr>
<tr>
<td>11. Ghana</td>
<td>1982</td>
<td>27</td>
<td>55</td>
<td>15</td>
<td></td>
</tr>
<tr>
<td>12. Ivory Coast</td>
<td>1982</td>
<td>7</td>
<td>35</td>
<td></td>
<td></td>
</tr>
<tr>
<td>14. Senegal</td>
<td>1982</td>
<td>4</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>South Asia</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>15. Sri Lanka</td>
<td>1979</td>
<td></td>
<td>47</td>
<td></td>
<td></td>
</tr>
<tr>
<td>16. Pakistan</td>
<td>1982</td>
<td></td>
<td>50</td>
<td>50</td>
<td>25</td>
</tr>
<tr>
<td><strong>Latin America</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>17. Bolivia</td>
<td>1978</td>
<td></td>
<td>50</td>
<td>70</td>
<td>35</td>
</tr>
<tr>
<td>18. Colombia</td>
<td>1977</td>
<td>12</td>
<td>50</td>
<td>70</td>
<td>35</td>
</tr>
<tr>
<td>19. Dominica</td>
<td>1982</td>
<td></td>
<td>70</td>
<td>30</td>
<td>21</td>
</tr>
<tr>
<td>20. Guatemala</td>
<td>1980</td>
<td>13</td>
<td>40</td>
<td>35</td>
<td>14</td>
</tr>
<tr>
<td>22. Jamaica</td>
<td>1982</td>
<td>7.6</td>
<td>62</td>
<td>49</td>
<td>30</td>
</tr>
</tbody>
</table>

Source: Various reports to World Bank Missions and to the International Labour Organization.

1 Net utilization = amount of hours utilized ÷ hours available x 100.
2 Total utilization = amount of hours utilized ÷ total working hours in the year x 100 (but the exact definition of total working hours is not clear).
B. Management Information Systems

2.05 Information systems in many public road authorities have not extended beyond financial budgetting, accounting and control, and it should not be surprising that they yield little or no information for purposes of performance monitoring and management. In recent years, however, a number of efforts have been made to extend modern management information systems into the realm of road authority equipment management. One notable example is the effort of the U.S. Federal Highway Administration, which first sponsored development of a generic Equipment Management System (Cresap, McCormick & Paget, Inc., 1978). It then sponsored pilot implementation of the system in at least four states (Idaho, Arkansas, New Mexico, and California), and an Equipment Management Symposium was held in 1982 (Hutchinson, 1982).

2.06 Another particularly important example is the system in use in the Main Roads Department of Western Australia (MRDWA) (Johnston and Harvey, 1981), which, after years of usage, is the most advanced system which the present authors have actually seen in use. Because the MRDWA system has accumulated much valuable information on life-cycle costs, it is referred to quite extensively in Chapter IV below.

2.07 However, none of the existing systems which were observed or found reported in the literature in the course of this study incorporated all the characteristics which were deemed essential from the point of view of economic management. First and foremost, all suffered from the fundamental flaw of ignoring interest charges on capital. This, of course, is a time-honored practice in financial accounting in many governments, but it is a nonetheless critical deficiency for economic management, for the use of capital does, of course, generate real costs to the economy; the consequences of this egregious practice are elaborated in Chapters IV and V below.

2.08 Second, it was also desired that the information system be able to establish costs of individual operations on a comparable basis with commercial contractors, so as to aid in identifying those activities which could in reality be more economically contracted out. Third, it was deemed essential that the information be as simple as possible (consonant with its objectives), and that it be capable of implementation in stages to ease the difficulties of implementation.

2.09 Consequently, the present study has given rise to development by the Crown Agents of a new framework for an equipment management information system, which is published as a separate volume (Eaton, 1984). An initial application of this new system is envisaged in Malawi in the near future. The simplest form of this system (Stage 1) provides a basis for monitoring and assessing the performance of the equipment fleet, and is described here below. The reader is referred to Eaton's report for the more detailed diagnostics and comprehensive costing system provided by the full system.
C. Monitoring Indices: Crown Agent's Information System (Stage 1)

2.10 There are five key terms used in this most basic system (Stage I):

(a) Normal working hours
(b) Utilization
(c) Availability
(d) Serviceability
(e) Idle time.

2.11 These terms are defined in Annex 2.1 to avoid misunderstandings which are likely to occur, particularly when utilization is referred to as a percentage of hours available instead of normal working hours or when deductions are made from the hours available for inclement weather, etc. Utilization is shown in hours to avoid this problem.

2.12 The four proposed reports for Stage 1 are described briefly below and samples are shown on the following pages. These key management reports are numbered (1-4); supplementary forms (shown in Annex 2.2) on which data are provided to enable the key information forms to be compiled are lettered (A-E). A detailed explanation of the use of all forms for Stage 1 is given in Annex 2.2.

(a) Monthly Equipment Availability and Utilization Report (Form 1). This will show for each item and class of equipment the availability and utilization expressed in hours or, in the case of motor vehicles, in distance run. This indicates by equipment utilization the effectiveness of the department as a whole, and by availability the effectiveness of the equipment maintenance branch.

(b) Monthly Report on Unserviceable Equipment (Form 2). This will show those items of equipment which were unserviceable at the end of the month and which had not been serviceable for 14 previous days. The objective of this report is not to indicate the level of equipment unserviceability (which can be obtained from the Equipment Availability and Utilization Report), but to show which items of equipment may warrant action to speed the acquisition of spare parts and repair. It indicates the effectiveness of the workshops and spare parts supply.

(c) Annual Equipment Audit Report (Form 3). This accounts for the equipment on charge and shows the annual changes in the numbers of the various classes, and the holdings at the beginning and end of the year, and location at the end of the year.

(d) Annual Staff Audit Report (Form 4). This indicates the staff establishment and strength by grade and location and shows all grades and the strengths at the beginning and end of the year. It's purpose is to help to identify existing or potential staff problems.
Form 1

Equipment Availability and Utilization Report for Month of

Country __________________________________________ Total no. of working hours in this month

Project __________________________________________ in YTD

HQ/Region ________________________________________

<p>| | | | | | | | | | | | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>(1)</td>
<td>(2)</td>
<td>(3)</td>
<td>(4)</td>
<td>(5)</td>
<td>(6)</td>
<td>(7)</td>
<td>(8)</td>
<td>(9)</td>
<td>(10)</td>
<td>(11)</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Equipment</th>
<th>Fleet/no. in class</th>
<th>Hours un-serviceable</th>
<th>Hours available</th>
<th>Hours/kms utilized</th>
<th>Fuel used in month</th>
</tr>
</thead>
<tbody>
<tr>
<td>Classes</td>
<td>Type</td>
<td>Month YTD</td>
<td>Month YTD</td>
<td>Month YTD</td>
<td>liters/ hr/100 km</td>
</tr>
</tbody>
</table>

Prepared by ___________ submitted by ___________ Rank ___________ Date ___________
Form 2

Monthly Report on Unserviceable Equipment

<table>
<thead>
<tr>
<th>Equipment Class</th>
<th>Type</th>
<th>Fleet/no</th>
<th>Date U/S*</th>
<th>Reason U/S*</th>
<th>Date Spares Ordered</th>
<th>Date Part Received</th>
<th>Date All Received</th>
<th>Est. Date &quot;S&quot;</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>(1)</td>
<td>(2)</td>
<td>(3)</td>
<td>(4)</td>
<td>(5)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Prepared by________ submitted by________ Rank_______ Date______

*U/S = unserviceable  S = serviceable
**Monthly Equipment Audit Report**

<table>
<thead>
<tr>
<th>Equipment Class</th>
<th>Establishment</th>
<th>No. at beginning of year</th>
<th>Additions during year</th>
<th>Disposals during year</th>
<th>No. awaiting disposal</th>
<th>Total No. at end of year</th>
<th>Number in Region at end of year</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Region</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>1</td>
</tr>
</tbody>
</table>

- 18 -
### Annual Staff Audit Report

<table>
<thead>
<tr>
<th>Staff by grade</th>
<th>Number at beginning of year</th>
<th>Additions during year</th>
<th>Number who left during year</th>
<th>&quot;Turnover&quot; for year</th>
<th>Number at end of year</th>
<th>Number in each Region</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Estab. Strength</td>
<td>New Promotions</td>
<td>Estab. Strength</td>
<td>1</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

- All staff leaving Total number at beginning of year

<table>
<thead>
<tr>
<th>Training Courses</th>
<th>Number attending</th>
<th>Duration of courses</th>
<th>Number passing</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
"Locating a spare part in stores beginning with the manufacturer's part number (where it normally begins) is an adventure in patience and persistence and only the hardy survive... In summary, there are large inventories of line items. They may never be used. What is in inventory is not completely known or cannot be easily located (but may eventually be found), and some items are in short supply because demand is not known or measured, and minimum stock levels have not been determined. Because of the confusion, some items have recently been ordered by the consultant and flown in when, indeed, they could have been located in inventory..." excerpts from a World Bank Supervision Report (November 1983).

III. **Spare Parts Supply Systems and Management**

A. **Introduction**

3.01 The spare parts problem is commonly considered the most important cause of inefficient utilization of equipment, for if the 'right spare part is not available at the right place at the right time' then equipment is inevitably kept unserviceable for long periods of time 'awaiting spares', an ubiquitous phenomenon in nearly all road authorities. Yet, seemingly paradoxically, in the same agencies there are typically large stocks of redundant spares.

3.02 Proper management of a spare parts supply function for a highways organization with a sizeable fleet is a large-scale, complex and costly undertaking. Typically, a machine has between 4,000-18,000 individual parts, comprised of some 2,000-4,000 different items. With 30-50 different types of machine, with only 2-3 different makes and 2-3 different ages, the complete range of different parts may easily exceed 500,000. While the majority may never need replacement, the number of different parts typically required to be stocked lies in the range of 50,000-100,000. The optimal level of investment in well-managed inventories at any point in time is of the order of 10% of the replacement cost of the fleet (or more, if stock replenishment is difficult), thus amounting to a few million dollars for a small highway authority fleet, to tens of millions for a large authority.

3.03 Optimal policies, of course, involve balancing the costs of equipment downtime against the costs of additional inventories of spares. Since the costs of equipment awaiting spares is normally of a much larger magnitude than the costs of additional spares inventories, some substantial redundancies in spares provision are desirable, unless lead times to replenish stockouts can be made very short. Unless very refined systems of spares requirements forecasting and inventory control are in place, as much as 25-30% of spares purchases will ultimately prove redundant. Where agencies do not have minimally adequate systems for forecasting needs, or where
mechanisms for regularly disposing of redundancies are inadequate, the accretion of obsolete stocks at any point in time may constitute the great majority of the entire stock.

B. Systemic Problems in Spare Parts Supply

3.04 The systemic causes of the spare parts problem can be categorized under six headings:

(a) Failure to assign, retain and motivate sufficiently qualified staff in the supplies management function;

(b) Failure to establish and maintain adequate management systems;

(c) Technical difficulties in forecasting precise needs;

(d) Proliferation of different makes, models and ages of equipment;

(e) Cumbersome bureaucratic procedures in procurement of new stocks and disposal of obsolete items;

(f) Inadequate financing or inappropriate budgetary control mechanisms.

3.05 Arguably, it is the general lack of appreciation of the importance, complexity and scale of the spare parts supply management function, coupled with the difficulties of retaining and motivating competent staff, that is the fundamental cause of the spare parts problem in so many road authorities. The effective head of such an important and complex function should normally be of the rank of a Chief Engineer, preferably with a university degree in industrial management (rather than mechanical or civil engineering), including specialization in modern methods of materials management. Key subordinate staff should have substantial specialized training in supplies management.

3.06 Associated with the failure to retain competent staff is the failure to maintain even minimally adequate management information systems. Indeed, deficiencies are often at the most basic level; inventories are not kept up-to-date, items are not properly labelled or shelved and stock control records are inadequate to locate items already in stock.

3.07 The central element of the spares supply function is anticipating future needs accurately. Under the best of circumstances there are serious technical difficulties in forecasting precise needs. The equipment manufacturers' recommendations, even where their intentions to help the purchaser (rather than simply offloading their own redundant stocks) can be trusted, are typically of limited value, because local conditions (e.g., skills level of operators and mechanics, physical working conditions and specific work tasks) can vary widely and because most manufacturers themselves have not given systematic attention to the problem. Specific data from local spares usage accumulated over time are required for accurate predictions, and this type of datum is normally not available from existing information systems.
3.08 The problem of forecasting requirements, and other problems, are exacerbated by the excessive proliferation of different makes, models and ages of equipment, which multiply spares requirements. This is due not only to the policies of foreign donors (para 1.05), but also to the presence of overaged items resulting from the combination of financial pressures and failure to apprehend the exceptionally heavy costs associated with keeping overaged equipment in service. Particularly where numbers are reduced to only a few pieces of a given type, the costs of maintaining spares stocks alone may exceed the benefits of keeping the item serviceable, yet cumbersome government procedures discourage disposing of non-economic equipment.

3.09 Cumbersome government procedures for procurement of new stocks and disposal of inevitable redundancies are another complicating factor in many cases. If procurement procedure could be streamlined, lower overall investments in inventories would suffice, since occasional stockouts could be quickly obtained on an as-needed basis. Low financial ceilings on procurement authorities for even senior management and requirements for multiple handling by different offices of government (e.g., departmental tender boards, central tender boards, treasury, etc.) virtually ensure delays in issuing purchase orders; they are also susceptible to the very malpractices which they are intended to prevent, since any individual may hold up even a large procurement until he is given sufficient incentive to clear it. Further delays may be encountered when suppliers insist on cash payment in advance because of government's known tardiness in settling its accounts. Where spares are procured under competitive tenders, inadequate attention may be given to quality specifications, and cheaply-priced, but poor-quality items obtained.

3.10 Often it is also difficult to dispose of outmoded items, so that they accumulate over time; in fact, several cases are known where the accretion of outmoded spares over time has left no shelf space so that the more recently acquired, and urgently needed, spares are left inaccessible in shipping crates, or worse, exposed to the elements, misplacement and pilferage.

3.11 Finally, it must be recognized that inadequate financing is a major problem in many cases. Budgetary restraints on recurrent accounts and shortages of foreign exchange restrict the amount invested in spares inventories and cumbersome import licensing practices delay emergency procurements. However, it should be noted that there are instances where investments in spares inventories have exceeded any conceivable need, and it must be emphasized that additional finance by itself is rarely, if ever, sufficient to solve the spare parts problem.

C. Elements of an Effective Spares Supply Systems

3.12 The spares supply function comprises six different elements:

(a) Anticipation of precise needs so that the great majority of demands (e.g. some 90%) can be met from immediately-available inventories;
(b) Comprehensive, up-to-date and easily accessible management information systems, including classification/coding systems (with cross-reference to different manufacturers and sources of supply and identification of commonalities), spot inventory, precise location, average life of each item on the machine, needs forecasting models, order thresholds (minimum quantities), economic order quantities and identification of redundancies and obsolete items for regular disposal;

(c) Adequate warehousing, labelling, shelving, preservative wrapping and security systems;

(d) Effective communications and distribution between central supply and workshops, including decentralization of fast-moving items with linkage of inventory records, preferably by remote entry terminals, to a computerized central inventory record system;

(e) Procurement facilitation with up-to-date knowledge of alternative sources of supply and market conditions, attention to prompt clearance of orders within the various governmental bodies concerned, freight management, facilitation through customs and prompt payment to suppliers; and

(f) Financial planning and budgetary management.

D. Conclusions

3.13 Unfortunately, few developing country road authorities have even minimally adequate spare parts supply systems. There are many contributory factors, but it can be argued that the underlying cause is the failure of top management to apprehend the scale, complexity and importance of the supply function, and the consequent failure to assign staff of commensurate abilities and training. The first important steps in remedying the problem are to win recognition of the importance of the task and assign able staff (or consultants) to identify alternative solutions.

3.14 Where the roads authority is unable to retain well qualified staff with specialized training in industrial management and materials supply functions within its own organization, it is essential that such services be arranged through contract with a well qualified organization, either in the form of a management services contract to manage inventories owned by the government or by contracting the entire supply function. Many countries, of course, rely on the manufacturers' local agents for these services. Indeed, as argued in Chapter I above, consideration should always be given to contracting all or part of the supplies and equipment service functions to one or more firms with particular expertise in this field, and in some circumstances it may be most economical for the government to hire all, or at least some of its equipment, from the private sector. To properly evaluate proposals for contracting such services, it is important
that the government have a good appreciation of its own costs, including interest on capital invested, which could be avoided. These issues are discussed in Chapters IV and V below.

3.15 Where contracting such functions on an acceptable basis is not possible, then a systematic program of technical assistance and training to upgrade the road authorities own capabilities is essential. The various elements of such a program are detailed in Chapter VI below.

3.16 Measures to deal with the various financing issues are discussed in Chapter I above.
IV. Life Cycle Costing and Fleet Replacement Policies

A. Introduction: Economic Costs and Equipment Decisions

4.01 Decisions concerning choice of equipment, equipment life and replacement should be governed by the principle of minimizing total economic costs per unit of output achieved (to an acceptable standard) by the equipment over its lifetime. These costs comprise capital, interest, maintenance and operation, less any salvage or scrap value. The sum of the future maintenance and operating costs is normally at least twice as large as the initial capital costs, so that the purchase price of the machine will not (or should not) normally be the dominant consideration in equipment selection decisions.

4.02 It is essential to take account of interest costs and time discounting to bring costs which occur in different years to a common basis. Life-cycle costs are thus defined as the discounted present value of the stream of economic costs which occur over the life of the equipment, which may also be transformed into equivalent annual costs or costs per hour. Since the opportunity cost of capital (or 'real' interest rate, after netting out the effect of general price inflation and risks) is rarely less than 12 percent in developing countries, interest rates typically add something more than 50 percent to the costs of ownership and thus play a major role in life-cycle costs and the determination of optimal equipment replacement and fleet management policies. Although interest costs are not always explicitly charged to the financial accounts of governmental equipment authorities, it is essential that they always be taken into account in decisions concerning equipment purchase and retirement to reach the correct economic decision. If interest costs are ignored, there will be a bias toward premature replacement of the equipment and a tendency to expand the size of the fleet beyond its most economic level, as well as a severe understatement of the costs of government equipment operations in comparison with private suppliers of equipment and services.

B. Prediction of Life-Cycle Costs

4.03 The normal life-cycle of equipment is that in the early years it has high availability, high productivity, and low maintenance costs, while in the later years maintenance costs rise, and availability and productivity fall sharply. In some cases, other operating costs (e.g., fuel) will also be lower in the early years and higher in the later years, but since variations

6/ Most commonly in decisions involving comparisons of two or more machines the technical characteristics are so similar that the different machines may be assumed to produce the same output to the same standards so that the decision criterion can be simplified so as merely to minimize total life cycle costs. But there are important exceptions, e.g., in comparing multi-purpose, fungible items with more specialized machines, when it is essential to compare differences in productivity.
in operating costs other than maintenance are not large, they are typically ignored. Often salvage values are minimal and can also be ignored, particularly in developing countries where there is no active market for second-hand construction equipment. Some allowance, however, must be made for increasing maintenance costs and declining availability and utilization. Indeed, the disruption to work progress of frequent breakdowns of older machines is the major cost consideration in determining equipment replacement.

4.04 An evaluation of the choice between any two machines, or whether to continue in service an existing machine or to replace it must therefore employ a forecast of the performance, maintenance costs, operating costs and, where applicable ultimate salvage value of each alternative. Unfortunately, a sound empirical basis for making such forecasts is rarely available. Unquestionably the best basis will be provided where substantial experience over several years with a significant number of identical (or very similar) machines, in similar use, has been accumulated and accurately reported in a readily accessible management information system, such as those discussed in Chapter II. It should be noted, however, that only the Crown Agents' system (Eaton, 1984) incorporates interest. If other systems are used, modifications will generally be required to incorporate interest costs.

4.05 The data base of the Main Roads Department of Western Australia - MRDWA (Johnston and Harvey, 1981) has progressed to the point that a generalized function of increasing equipment maintenance costs over the normal life of an individual machine, or class of like machines, has been statistically derived. For simplicity, operating costs are assumed constant per hour of use over the life of the machine. The generalized form of the equation for maintenance costs, based on the particular equipment fleet and usage conditions of Western Australia, corresponds to the simple power function:

\[ M = a H^b \]  
(Eq. 1)

where

\[ M = \text{cumulative maintenance costs} \]
\[ H = \text{cumulative hours worked} \]
\[ a, b = \text{statistically-derived parameters for a particular machine or class of machine} \]

4.06 Numerical results for Eq. (1) are illustrated in Table 4.1 (cols. 5-7), and depicted graphically in Fig. 4.1, where values are shown for two individual machines in a particular class of heavy motor graders and for the composite average for all such machines in the MRDWA fleet. While the MRDWA
### Table 4.1

**Equipment Utilization and Life-Cycle Costs Excluding Interest Charges - Heavy Motor graders - An Australian Example**

<table>
<thead>
<tr>
<th>Utilization-Downtime (Hours)</th>
<th>Cumulative Costs Thru Year Y ($A)</th>
<th>Lifetime Average Costs Per Year ($A)</th>
<th>Incremental Costs for Year Y ($A)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Year</td>
<td>Utilization in Year Y</td>
<td>Downtime in Year Y</td>
<td>Unit No.</td>
</tr>
<tr>
<td>(1)</td>
<td>(2)</td>
<td>(4)</td>
<td>(5)</td>
</tr>
<tr>
<td>1</td>
<td>1500</td>
<td>0</td>
<td>1500</td>
</tr>
<tr>
<td>2</td>
<td>1450</td>
<td>50</td>
<td>2950</td>
</tr>
<tr>
<td>3</td>
<td>1400</td>
<td>100</td>
<td>4350</td>
</tr>
<tr>
<td>4</td>
<td>1340</td>
<td>150</td>
<td>5890</td>
</tr>
<tr>
<td>5</td>
<td>1270</td>
<td>200</td>
<td>6960</td>
</tr>
<tr>
<td>6</td>
<td>1190</td>
<td>300</td>
<td>8150</td>
</tr>
<tr>
<td>7</td>
<td>1100</td>
<td>400</td>
<td>9250</td>
</tr>
<tr>
<td>8</td>
<td>1000</td>
<td>500</td>
<td>10250</td>
</tr>
<tr>
<td>9</td>
<td>900</td>
<td>600</td>
<td>11150</td>
</tr>
<tr>
<td>10</td>
<td>800</td>
<td>700</td>
<td>11950</td>
</tr>
<tr>
<td>11</td>
<td>700</td>
<td>800</td>
<td>12650</td>
</tr>
<tr>
<td>12</td>
<td>600</td>
<td>900</td>
<td>13250</td>
</tr>
<tr>
<td>13</td>
<td>500</td>
<td>1000</td>
<td>13750</td>
</tr>
<tr>
<td>14</td>
<td>400</td>
<td>1100</td>
<td>14150</td>
</tr>
<tr>
<td>15</td>
<td>300</td>
<td>1200</td>
<td>14450</td>
</tr>
</tbody>
</table>

**Notes:**
- Cols. 2, 3, 4: Assumed values, based on an average 1250 hours per annum lifetime utilization.
- Cols. 5, 6, 7: Costs as predicted from eq. (1) based on the cumulative utilization given in col. (4).

Coefficients of eq. (1):
- Col. 5: 0.03119
- Col. 6: 1.6128
- Col. 7: 0.05931

Col. 8: Cumulative downtime thru year Y multiplied by $50 per hour hire rate for replacement machine including costs to the site.

Cols. 9 & 10: Cols. 7 and 8 divided by col. 1.

Col. 11: $A100,000 purchase price of machine divided by col. 1.

Col. 12: The sum of cols. 9 + 10 + 11 for each year.

Col. 13: Col. 7 for the given year less col. 7 for the preceding year.

Col. 14: Col. 1 x $50 per hour.

Col. 15: The sum of cols. 13 and 14 for each year + $A1000,000 in year 1.
Figure 4.1: EQUIPMENT LIFE-CYCLE MAINTENANCE COSTS Relative to Utilization

Cumulative Costs:
- Unit No. 773
- Unit No. 3661
- Maintenance average

Cumulative Usage (1000 Hours) vs. Cumulative Maintenance Costs ($1000s)
experience indicates that the general form of Eq. (1) is appropriate for all classes of major equipment, different machines will, of course, have different 'a' and 'b' coefficients. Even nominally identical units from the same manufacturer can have quite different life-cycle maintenance costs, and this applies a fortiori as machines with increasingly different characteristics (horsepower, weight, manufacture, etc.) are compared.

4.07 Some important conclusions can be drawn from Eq. (1). First, it should be noted that cumulative maintenance costs are very large, typically summing over an average life of 8 to 12 years, in undiscounted values, to approximately 150 to 225 percent of the original capital cost (i.e., purchase price of the machine, which is approximately A$100,000), or, when discounted at 12 percent, to some 65 to 85 percent (as will be seen from Table 4.2, col. 4). Second, maintenance costs increase rapidly in the early years, but as the absolute amount grows large, the rate of increase slows considerably in later years, contrary to what is often assumed in equipment management analyses. Thus, maintenance costs per se do not appear to be the dominant consideration in equipment replacement decisions.

4.08 Experience in MRDWA indicates that the decline in equipment availability and utilization (i.e. downtime) increases much more rapidly than maintenance in the later years of equipment life. The values for downtime in Tables 4.1 and 4.2 have been assumed in accordance with this principle on the basis of an average utilization of 1250 hours per year over an 8-year lifetime; values beyond 8 years have been extrapolated in rough approximation with fragmentary observations from developing countries. Estimates of the costs of downtime are based on the assumption that a replacement machine will be provided to the equipment user to make up for downtimes; if a replacement machine is not provided, the consequential losses in terms of the work not being done and other resources being idled can reasonably be assumed to be rather larger. The costs of the replacement machine are taken at A$50 per hour, or approximately twice the cost of a machine hour under optimal conditions, to reflect the costs of idle time on standby, mobilization, unavoidable minimum work stoppages, etc. Under these circumstances, as can be seen from Table 4.1, col. 6, downtime losses become very large and ultimately dominate equipment replacement decisions.

C. Optimum Economic Life of Equipment

4.09 At some point in the life of a machine the prospective increase in maintenance and downtime costs of the old machine exceed the annualized costs of purchasing a new machine. In Table 4.1, where interest costs have been ignored, this point is reached between year 6 and 7, as can be seen by comparing cols. 12 and 15, or by inspection of Figure 4.2.

7/ When operating costs (fuel, operator wages, etc.) are included, the capital costs of the machine typically constitute only about 30 percent of total life-cycle costs.
Table 4.2

Equipment Utilization and Life-Cycle Costs Including Interest Charges at 12% Per Annum

(For the example given in Table 4.1)

<table>
<thead>
<tr>
<th>Year</th>
<th>Present Worth Factor</th>
<th>Maintenance Costs in Year</th>
<th>Life-Cycle Costs in Year</th>
<th>Total Life-Cycle Costs</th>
<th>Total Life-Cycle Costs Discounted to Year 1</th>
<th>Equivalent Uniform Annual Costs</th>
<th>Incremental Maintenance Costs</th>
<th>Capital Recovery Costs for Year</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>(1)</td>
<td>(2)</td>
<td>(3)</td>
<td>(4)</td>
<td>(5)</td>
<td>(6)</td>
<td>(7)</td>
<td>(8)</td>
</tr>
<tr>
<td>1</td>
<td>0.8929</td>
<td>4983</td>
<td>0</td>
<td>0</td>
<td>1.12000</td>
<td>5581</td>
<td>0</td>
<td>112000</td>
</tr>
<tr>
<td>2</td>
<td>.7972</td>
<td>8381</td>
<td>13264</td>
<td>1993</td>
<td>.59170</td>
<td>7907</td>
<td>1179</td>
<td>59170</td>
</tr>
<tr>
<td>3</td>
<td>.7118</td>
<td>9589</td>
<td>22953</td>
<td>3559</td>
<td>.41635</td>
<td>9556</td>
<td>2312</td>
<td>41635</td>
</tr>
<tr>
<td>4</td>
<td>.6353</td>
<td>9822</td>
<td>32775</td>
<td>5084</td>
<td>.32923</td>
<td>10791</td>
<td>3502</td>
<td>32923</td>
</tr>
<tr>
<td>5</td>
<td>.5674</td>
<td>9475</td>
<td>42250</td>
<td>6525</td>
<td>.27741</td>
<td>11721</td>
<td>4761</td>
<td>27741</td>
</tr>
<tr>
<td>6</td>
<td>.5066</td>
<td>8766</td>
<td>51016</td>
<td>7852</td>
<td>.24323</td>
<td>12409</td>
<td>6084</td>
<td>24323</td>
</tr>
<tr>
<td>7</td>
<td>.4523</td>
<td>7837</td>
<td>58833</td>
<td>9046</td>
<td>.21912</td>
<td>12896</td>
<td>7463</td>
<td>21912</td>
</tr>
<tr>
<td>8</td>
<td>.4039</td>
<td>6786</td>
<td>56639</td>
<td>10098</td>
<td>.20130</td>
<td>13213</td>
<td>8889</td>
<td>20130</td>
</tr>
<tr>
<td>9</td>
<td>.3606</td>
<td>5748</td>
<td>51387</td>
<td>10818</td>
<td>.18768</td>
<td>13398</td>
<td>10318</td>
<td>18768</td>
</tr>
<tr>
<td>10</td>
<td>.3220</td>
<td>4764</td>
<td>71511</td>
<td>11270</td>
<td>.17698</td>
<td>13477</td>
<td>11724</td>
<td>17698</td>
</tr>
<tr>
<td>11</td>
<td>.2875</td>
<td>3857</td>
<td>80008</td>
<td>11500</td>
<td>.16842</td>
<td>13475</td>
<td>13094</td>
<td>16842</td>
</tr>
<tr>
<td>12</td>
<td>.2567</td>
<td>3039</td>
<td>83047</td>
<td>11352</td>
<td>.16144</td>
<td>13407</td>
<td>14416</td>
<td>16144</td>
</tr>
<tr>
<td>13</td>
<td>.2292</td>
<td>2315</td>
<td>85362</td>
<td>11460</td>
<td>.15568</td>
<td>13289</td>
<td>15686</td>
<td>15568</td>
</tr>
<tr>
<td>14</td>
<td>.2046</td>
<td>1684</td>
<td>87046</td>
<td>11253</td>
<td>.15087</td>
<td>13133</td>
<td>16899</td>
<td>15087</td>
</tr>
<tr>
<td>15</td>
<td>.1827</td>
<td>1144</td>
<td>88190</td>
<td>10962</td>
<td>.14682</td>
<td>12948</td>
<td>16055</td>
<td>14682</td>
</tr>
</tbody>
</table>

NOTES:

Cols. 2 & 7: Present worth and capital recovery factors (from any standard interest tables).
Col. 3: Col. 2 multiplied by col. 13 of Table 4.1.
Col. 4: Cumulation through year Y of col. 3.
Col. 5: Col. 2 multiplied by col. 14 of Table 4.1.
Col. 6: Cumulation through year 4 of col. 5.
Col. 8: Col. 4 multiplied by col. 7.
Col. 9: Col. 6 multiplied by col. 7.
Col. 10: $100,000 purchase price of the machine multiplied by col. 7.
Col. 11: Sum of cols. 8 + 9 + 10.
Col. 12: Sum of cols. 11 + 12 of Table 4.1.
Figure 4.2: EQUIPMENT UTILIZATION AND LIFE-CYCLE COSTS
Excluding Interest Charges

Lifetime Average Costs per year:
- Total
- Capital Recovery
- Downtime
- Maintenance

Incremental Costs:
- Maintenance + Downtime + Capital

Years

Hours (10^3) Utilization

World Bank - 306682
4.10 In Table 4.2 interest charges at 12 percent per annum have been introduced.\textsuperscript{8} Future cost streams of maintenance and downtime have been converted into discounted present values (cols. 3 and 5, respectively) by multiplying by the Present Worth Factor for the given year (col. 2), summed to give life-cycle discounted present values for each alternative life (cols. 4 and 6), and then converted into equivalent uniform annual costs (cols. 8, 9 and 10) by multiplying present values by the Capital Recovery Factor (col. 7) for each assumed life. The results of Table 4.2 are graphed in Figure 4.3.

4.11 The effect of introducing interest rates can be seen by comparing col. 12 of Table 4.1 with col. 11 of Table 4.2. The latter figures are about 10 to 15 percent higher in the range of 6 to 9 years life. Most importantly, the minimum equivalent annual cost (and the point where incremental costs equal average cost) occurs for a lifetime of 8 to 9 years, when interest costs are incorporated into the analysis, rather than 6 to 7 years when interest costs are ignored.

4.12 It will also be seen that the costs of keeping an overaged price of equipment in service increase rapidly beyond the point of optimum economic life. While the lifetime average, or equivalent uniform annual costs, rises only very slowly because of the averaging process, the incremental costs rise quite rapidly. For example, keeping a 12-year-old machine in service an additional year occasions incremental costs of over $60,000, whereas the cost, including full equipment depreciation and interest, for a machine with optimum life is only $42,232 per year. Thus, the equipment agency would be incurring excess costs of nearly $18,000, or approximately 42 percent above the optimum.

4.13 Of course, it must be recognized that any advance forecast of optimum economic life is only a planning exercise subject to wide margins of error. It is essential to make some such forecast for purposes of planning financial flows and spares provisioning. But any decision to replace an individual item or fleet when it nears the end of its serviceable life should not be based on any such \textit{a priori} forecast of optimum economic life (made several years earlier), but rather on a year-by-year and case-by-case analysis, involving periodic mechanical assessments of the condition of the machine. Careful monitoring of costs and serviceability on a regular basis will reveal when the yearly costs of maintenance and downtime are approaching the range of the annual costs of providing a new machine. At this stage decisions concerning any major repairs should be based on a careful assessment of the overall mechanical condition of the machine, the probable length and dependability of service before additional major repairs would be necessary, and a comparison with the annual costs of replacement. Obviously, a machine with demonstrably higher than average maintenance costs (such as unit no. 3661 in Table 4.1) would be replaced much earlier than the average, particularly if there is an active second-hand market. While an individual unit with lower

\textsuperscript{8} The reader who is unfamiliar with the type of calculations shown in Table 4.2 may wish to refer to a standard text in the field of engineering economy, e.g., Grant, Ireson and Leavenworth (1982).
Figure 4.3: EQUIPMENT UTILIZATION AND LIFE-CYCLE COSTS
Including 12% Interest

Equivalent Uniform Annual Costs:
- Total
- Capital Recovery
- Downtime
- Maintenance

Incremental Costs:
- Maintenance + Downtime + Capital

World Bank - 30658.3
than average costs (e.g. unit no. 773) would normally be kept longer than the average life, this could be curtailed where only a few items of this type remain in the fleet, because of the difficulty and high costs of stocking spares for only a few units. Furthermore, a low and unpredictable availability of an average machine causes its hourly operation cost to increase, and is disruptive for an orderly work and production schedule.

D. Fleet Rationalization/Standardization

4.14 As has been discussed in earlier chapters, a multiplicity of different types, makes and ages of different machines, unfortunately a common phenomenon in road authorities in developing countries, can create severe difficulties in servicing of the equipment. Consequences include:

(a) increased investment, interest, warehousing, procurement, handling, obsolescence and administration costs related to the multiplication of requisite spares inventories;

(b) increased costs of mechanics and operators' training and lowered efficiencies in servicing diverse items;

(c) normally a substantially lower level of equipment service and utilization, since the probability of a stockout of key spare parts rises with the number of items required (despite increased investment in inventories).

4.15 There are, obviously, tradeoffs among these items; the larger the investment in extra inventories, the lower the probability of stockouts of needed items, but in practice some compromise is usually struck, and both items (a) and (c) are commonly held to be extremely serious concerns by experienced fleet managers.

4.16 Private companies often find it more profitable to standardize on one or a few makes, types, and ages to minimize these problems, with the resulting savings more than offsetting any premium which may have to be paid for standardization in the purchase price of the specific equipment and its spare parts.

4.17 In evaluating tenders for fleet purchase for governmental organizations, careful attention should be given to optimizing these various cost tradeoffs; in practice, this will mean giving rather more weight to standardization or rationalization than has normally been the case. In the following paragraphs we address the problem of estimating the magnitude of the premium which an equipment fleet owner should be prepared to pay for standardizing on a particular machine or series of machines. The issue of standardization in tender evaluation is then treated.
1. **Quantifying the Benefits of Fleet Rationalization/Standardization**

4.18 Unfortunately, a search of the mechanical engineering literature has yielded no substantial empirical evidence on quantification of the benefits of fleet standardization, and we have found no satisfactory basis for evaluating these. Nonetheless, the problem has been addressed in some large-equipment owning organizations, and we draw upon one such case, and a series of assumptions, to illustrate the magnitudes involved.

   a) **Spare Parts Inventory Holding Costs**

4.19 Consider a moderately large fleet which consists of 50-100 units of each of the machines shown in Table 4.3. Altogether the fleet comprises some 800 items of equipment and the total investment (at January 1983 prices) amounts to some $125.9 million.

**Table 4.3**

<table>
<thead>
<tr>
<th>Machine Type/Fly Wheel HP</th>
<th>Total Parts</th>
<th>Total Different Parts</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bulldozer 80</td>
<td>7,596</td>
<td>2,075</td>
</tr>
<tr>
<td>Bulldozer 165</td>
<td>8,341</td>
<td>2,214</td>
</tr>
<tr>
<td>Bulldozer 200</td>
<td>11,226</td>
<td>2,641</td>
</tr>
<tr>
<td>Wheel Loader 100</td>
<td>7,295</td>
<td>2,423</td>
</tr>
<tr>
<td>Wheel Loader 155</td>
<td>9,243</td>
<td>2,795</td>
</tr>
<tr>
<td>Wheel Loader 200</td>
<td>9,818</td>
<td>2,875</td>
</tr>
<tr>
<td>Motor Grader 125</td>
<td>12,348</td>
<td>2,691</td>
</tr>
<tr>
<td>Motor Grader 135</td>
<td>12,238</td>
<td>2,701</td>
</tr>
<tr>
<td>Wheel Dozer 210</td>
<td>9,451</td>
<td>2,821</td>
</tr>
<tr>
<td>Tractor Scraper 450</td>
<td>17,789</td>
<td>3,728</td>
</tr>
<tr>
<td>Excavator 135</td>
<td>12,715</td>
<td>2,337</td>
</tr>
<tr>
<td>Interchangeable parts if all one manufacture</td>
<td>13,740</td>
<td></td>
</tr>
<tr>
<td>Total number of different parts with complete standardization</td>
<td>15,561</td>
<td></td>
</tr>
</tbody>
</table>
4.20 If there is complete standardization with all units of all types of machines being provided by one manufacturer (Case A), the maximum number of different parts required would be 15,561. If different brands of any machine were introduced, the requisite parts items would essentially be multiplied, since the commonality of spare parts (at least of the more expensive items) among different manufacturers is quite limited. If all machines of a given type were provided by a single manufacturer, but a different manufacturer provided each different type (Case B), then the total number of different parts would be increased to 29,301, or an increase of 88.3 percent. If proliferation extended further (as is often the case) so that different units of the same type of machine were provided by different manufacturers (Case C), the number of items in the requisite spare parts inventory could increase several-fold. For purposes of illustration we shall assume for Case C that there are three different makes for each type of machine or (3 x 11) = 33 different manufacturers for the 800 items in the fleet.

4.21 If we employ the manufacturer's recommended stock levels for 2,000 operating hours of each machine in moderately heavy usage together with list prices at January 1983, the monetary costs of different levels of inventory holdings can be calculated as shown in Table 4.4. The recommended investment in parts inventory is, respectively, $2.67, $5.03, and $15.08 million. Taking annual interest costs at 12%, warehousing, handling and administration costs at 35%, and obsolescence at 10%, annual costs are, respectively, $1.52, $2.87, and $8.59 million. Thus, semi-standardization increases annual inventory holding costs by (2.85-1.52) = $1.33 million, while moderate proliferation increases these costs by (8.59-1.52) = $7.07 million. Compared to the annual fleet ownership costs of $25.3 million ($125.9 million amortized at 12% over 8 years), these costs amount to 5.3 percent and 27.9 percent, respectively.

b) Costs of Mechanics' and Operators' Training

4.22 We have no evidence to quantify extra training costs to prepare mechanics and operators for a proliferation of makes and models. But if we assume that a typical training budget to deal with such staff for a fully standardized 800-item fleet is of the order of $200,000 per year, and we take fifty percent of this amount, or $100,000, as representing the extra costs in Case B, or doubling in Case C, we see that the costs involved are not large, constituting, respectively, about 0.4 and 0.8 percent of the annual fleet ownership costs of $25.3 million.

9/ Depreciation of the initial investment is not included in the annual costs, since the full inventory is assumed ultimately to be fully utilized (other than the 10% p.a. obsolescence).
Table 4.4

Spare Parts Inventory Costs with Proliferation of Equipment Makes

<table>
<thead>
<tr>
<th>800 Item Fleet: Total Replacement Cost = $125.9 m</th>
</tr>
</thead>
<tbody>
<tr>
<td>Annual Amortization @ 12% over 8 years = $ 25.3 m</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Extra Costs</th>
<th>Case A</th>
<th>Case B</th>
<th>Case C</th>
<th>Case A</th>
<th>Case C-A</th>
</tr>
</thead>
<tbody>
<tr>
<td>(One Mfg. (One Mfg. (Three Mfg.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>all machines) Each type) Each Type) Case B-A Case C-A</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>---------------</td>
<td>--------</td>
<td>--------</td>
<td>--------</td>
<td>--------</td>
<td>----------</td>
</tr>
<tr>
<td>1. Recommended Inventory Investment (2000 hours utilization in moderate duty)</td>
<td>$ 2,668</td>
<td>5,025</td>
<td>15,075</td>
<td>2,357</td>
<td>12,407</td>
</tr>
<tr>
<td>2. Annual Interest @ 12%</td>
<td>320</td>
<td>603</td>
<td>1,809</td>
<td>283</td>
<td>1,489</td>
</tr>
<tr>
<td>3. Annual Warehousing Handling &amp; Administration @ 35%</td>
<td>934</td>
<td>1,759</td>
<td>5,276</td>
<td>825</td>
<td>4,342</td>
</tr>
<tr>
<td>4. Annual Obsolescence @ 10%</td>
<td>267</td>
<td>503</td>
<td>1,508</td>
<td>236</td>
<td>1,241</td>
</tr>
<tr>
<td>Total Annual Costs (lines 2+3+4 )</td>
<td>1,521</td>
<td>2,865</td>
<td>8,593</td>
<td>1,344</td>
<td>7,072</td>
</tr>
</tbody>
</table>

c) Increased Downtime of Equipment Fleet

4.23 In the absence of empirical evidence from any source the costs associated with increased equipment downtime occasioned by proliferation of different makes and models can only be hypothesized. From a series of reasonable assumptions it is easy, however, to demonstrate that these costs are likely to be of substantial magnitude. Consider that in a reasonably efficient organization, the total downtime for repairs for any given piece of equipment may amount to 400 hours per year, and assume that only one-fourth of this time, or 100 hours, is spent awaiting spares, corresponding to a decision to maintain inventories at such a level as to meet 90 percent of spares requirements off the shelf. The downtime awaiting spares must increase in relation to the probabilities of stock-out of the requisite parts, which in turn increases with the proliferation of different makes, models and ages, since it is unlikely that the same percentage coverage of potential spares needs will be met as requisite inventories are multiplied. Let us further assume that for the three cases under consideration that the stocking levels are maintained so as to meet the following service levels:
In this example, the extra equipment downtime for Case B compared to Case A adds \((50+1250) = 4\) percent to equipment fleet ownership costs, while Case C adds \((100+1250) = 8\) percent. Of course, by further increasing investments in spares inventories the same 90 percent service level could be achieved, but as we have already seen, these costs are quite large.

4.24 The different components of the extra costs can now be summarized as a percentage of the fleet ownership costs as follows:

<table>
<thead>
<tr>
<th>CASE</th>
<th>A</th>
<th>B</th>
<th>C</th>
</tr>
</thead>
<tbody>
<tr>
<td>% needs met from inventory</td>
<td>90</td>
<td>85</td>
<td>80</td>
</tr>
<tr>
<td>% needs not met from inventory</td>
<td>10</td>
<td>15</td>
<td>20</td>
</tr>
<tr>
<td>Corresponding downtime awaiting spares</td>
<td>100</td>
<td>150</td>
<td>200</td>
</tr>
<tr>
<td>Corresponding Annual Utilization</td>
<td>1250</td>
<td>1200</td>
<td>1150</td>
</tr>
</tbody>
</table>

This indicates that an organization facing these particular circumstances should be prepared to pay up to \((36.7-9.7) = 27\) percent to standardize at least each class of machine, and it should be prepared to pay up to an additional 9.7 percent to completely standardize its fleet on a single manufacturer, where feasible.

4.25 These specific findings, of course, depend on the many assumptions employed in the analyses in the absence of firm empirical evidence, and the exact quantities would shift substantially if different assumptions were employed. It is believed that in normal practice what often happens with proliferation is that investments in spares inventories increase rather less, and downtime increases rather more than depicted in this illustration. The only valid general conclusion which can be drawn is that the benefits of standardization are likely to be significant in relation to the total ownership costs of an equipment fleet, and therefore quite significant indeed in relation to the price differentials between tenders of different manufacturers. Consequently it is of great importance that the equipment fleet organization collect relevant information to better quantify these costs and explicitly incorporate them in decisions concerning equipment selection and standardization.

2. Tender Evaluation

4.26 Many different systems exist for evaluation of competing bids in public tenders for equipment. It is quite common (but, unfortunately, not universal) practice that factors other than the initial equipment price are
incorporated in the evaluation of tenders, e.g., differentials in performance and productivity, operating and maintenance costs, availability of spare parts and service, cost of spare parts, and delivery schedules. Recently the Asian Development Bank, Inter-American Development Bank and the World Bank jointly issued Sample Bidding Documents - Procurement of Goods (September 1983) which suggest various acceptable systems of bid evaluation. The preferred system, where sound data are available from the purchasing agency's experience, is a form of life-cycle costing which would encompass all of the above factors.

4.27 Such complete information is not yet commonly available, however, and various forms of merit point systems are widely used. The system suggested by the Sample Bidding Documents, in the absence of more complete information, is typical of the many systems in common use. The purchasing authority establishes evaluation weights for the following factors within a suggested range:

<table>
<thead>
<tr>
<th>Factor</th>
<th>Range</th>
</tr>
</thead>
<tbody>
<tr>
<td>Evaluated price of the equipment</td>
<td>50 - 70</td>
</tr>
<tr>
<td>Price of common list spare parts</td>
<td>10 - 20</td>
</tr>
<tr>
<td>Technical features, maintenance and operating costs</td>
<td>10 - 20</td>
</tr>
<tr>
<td>Service and spare parts availability</td>
<td>10 - 20 10/</td>
</tr>
<tr>
<td>Standardization</td>
<td>10 - 20</td>
</tr>
<tr>
<td>Total</td>
<td>100</td>
</tr>
</tbody>
</table>

4.28 Consideration of life-cycle cost streams, some major elements of which have been examined in detail above, indicates that these typical weights tend to overstate substantially the importance of the initial purchase price of the equipment. Over the life of the equipment the discounted present value of maintenance costs (labor and parts) will normally reach about 65-85 percent of the initial purchase price of the equipment, and when operating costs are encompassed, it will be seen that the initial equipment price may amount to no more than one-fourth to one-third of total life-cycle costs. Consequently, it is recommended that every agency which holds any substantial fleet adopt information systems that will provide the basis for comprehensive life-cycle costing, and that these costs be incorporated explicitly in replacement and procurement decisions.

10/ This range suits a well-managed organization, able to order and pay quickly the spare parts within the country and overseas. In the case of a highway department facing lack of foreign currency and cumbersome regulations, larger weight should be given to this criterion.
V. Cost Accountability, Hire Schemes and Funding

A. Deficiencies in Current Practices

5.01 Fundamental weaknesses in very many equipment-owning public authorities are the twin failures to properly account for, and to hold users accountable for, the full costs of owning and operating equipment.

5.02 These problems are often found in association with failure to provide funding for regular renewal of equipment, since, costs not being covered by the users, replacement depends on subsidies from the general exchequer, which are typically sporadic. Often cost accounts are incomplete, inaccurate and inaccessible, and what information is available tends to seriously understate true costs. Major deficiencies commonly encountered in costing and budgeting are (i) failure to recognize interest costs on the capital invested; (ii) failure to make adequate allowances for price inflation in replacement charges; and (iii) failure in many cases even to charge the user for depreciation of the equipment at original cost.

5.03 Obviously, the third case is the most serious, and it is, unfortunately, not uncommon. But almost as serious is the virtually universal practice in government accounts of ignoring interest costs. For assets typically depreciated over 8 years, interest of only 12 percent per annum adds 48 percent to the costs of depreciation, and where budgets are constrained, as is often the case, the opportunity costs of capital will be much higher.11/ Where the rate is 25 percent, cumulative interest charges will equal the capital investment. Price inflation has also been a significant problem in recent years, with the cost of equipment increasing at an average rate of approximately 15 percent per annum between 1973 and 1980, although prices have been essentially constant since 1980.

5.04 Such major understatement of the costs of equipment services to government agencies has led to important distortions in resource allocation, including:

(a) inadequate attention given to gaining effective utilization of the existing equipment fleet;

(b) a tendency to employ foreign-exchange-intensive equipment for tasks where labor-based methods may in reality be cheaper;

(c) a tendency for the public roads authority to undertake tasks on a force account basis which in reality could be done more cheaply by private contractors;

11/ It should be noted that in many road authorities in developing countries today, the marginal returns to further expenditures on road maintenance, (if only funds were available) has been shown to exceed 50 percent per annum.
(d) a tendency to over-invest in the publicly-held equipment fleet, which may be much larger than necessary if only it were utilized more effectively; and

(e) a tendency, where funding for equipment renewal is tied to cost-recovery from the users and is thus inadequate for timely replacement of worn-out equipment, to attempt to maintain and operate equipment well past the point where it would be more economic to replace it.

B. **Plant Hire Schemes**

1. **Objectives**

5.05 Institution (or revitalization) of plant hire schemes (or, in their broader formulation, hire-funding schemes) provides a potential solution to these difficulties. A hiring scheme is one in which the equipment-owning department or agency hires out equipment to the user at a hire charge sufficient to recover the cost of owning the equipment and providing ancillary services. As the service provided varies, so will the hire charge. In some schemes, fuel, drivers or operators are supplied with the equipment and the user is charged accordingly. In others, the user provides them. Charges for some schemes include the cost of monthly paid staff and in others this is paid from a central government account. Where the hiring charge includes an element for the renewal or replacement of the equipment, and the agency retains control over the depreciation reserve funds thus generated, the scheme may be described as a hiring and funding scheme.

5.06 The schemes considered in this paper all have a renewals element in the charges and an account from which, at least in theory, new equipment can be purchased. The most desirable scheme will accept all costs connected with the provision of the service in order to obtain a full cost of hire that might be compared fairly with the cost of hiring the equipment from the private sector.

5.07 The main objectives of equipment hiring schemes are:

(a) To motivate the user to maximize utilization and productivity and minimize the time on hire;

(b) To motivate the supplier to maximize equipment availability and minimize down time or unserviceability and maintenance costs, since the lower the downtime the greater the hiring and revenue earning potential;

(c) To motivate the supplier to minimize the quantity of equipment held to meet the needs of the users. Excessive quantities of equipment will reduce overall utilization thereby increasing the cost, reducing net earnings and creating a greater workload for the maintenance and repair department;
(d) To improve utilization of equipment by the flexibility resulting from the sharing of equipment by various users, when this is feasible, instead of each user having his own;

(e) To facilitate general "economic life" policies and bring utilization and cost statistics into the open;

(f) To recover from the user the cost of the service provided;

(g) To build up a reserve of funds which can be used by the equipment supplier or department hiring out equipment to buy new equipment when the old is beyond economical repair, taking into account the effect of inflation on purchase price.

2. **Costing and Pricing**

5.08 The two primary considerations in structuring hire rates are, first, to make costs to the user reflect as accurately as possible the costs to the supplying agency, and, second to ensure administrative simplicity. These two rules are sometimes in conflict, but exactitude to the last decimal is less important than ease of administration, and a reasonable compromise can normally be achieved. Typically hiring charges are usually levied on the basis of: (i) time on hire whether the equipment is used or not; (ii) time actually worked while on hire; or (iii) a combination of both. A typical example of a hire charge structure of the last type is given in Fig. 5.1.

5.09 The determination of costs related to specific items of equipment and appropriate allocation of overheads will, of course, require a sound system of cost accounting. This host of issues is addressed in Eaton (1984), which sets out in detail a comprehensive system of cost accounting for an equipment authority. The principal concern is to ensure that the full costs of equipment ownership (at replacement cost with interest) as well as maintenance costs and overheads are covered.

5.10 It is reiterated that the most desirable scheme will comprehend all costs connected with the provision of the equipment service in order to obtain a full cost of hire that can validly be compared with the cost of hiring the equipment from alternative sources. Wherever the possibility exists, such comparisons should regularly be made, and the equipment users should have the freedom to choose the cheaper supplier. Where private suppliers may be induced to provide competing equipment and services, an adjustment would normally have to be made for purposes of comparison to net out any corporate income or indirect taxes levied on the private supplier from which the government supplier would be exempt.

3. **Budgeting and Funding**

5.11 If full costs are to be recovered from the user, then corresponding provisions must be made in the user's budgets. In few road authorities today is this the case. Indeed, the general downward pressure on road bud-
FIGURE 5.1
HIRE CHARGES - PLANT

MOBILE PLANT (including operator)

<table>
<thead>
<tr>
<th>Group</th>
<th>Equipment</th>
<th>Hour Rate</th>
<th>Day Rate</th>
</tr>
</thead>
<tbody>
<tr>
<td>901</td>
<td>Tractors, (Tracked, incl. Doozers &amp; Shovel)</td>
<td>30.00</td>
<td>18.00</td>
</tr>
<tr>
<td>901/4</td>
<td>DoD</td>
<td>30.00</td>
<td>18.00</td>
</tr>
<tr>
<td>901/6</td>
<td>DoC</td>
<td>42.00</td>
<td>18.50</td>
</tr>
<tr>
<td>901/9</td>
<td>DoD</td>
<td>67.00</td>
<td>27.00</td>
</tr>
<tr>
<td>902</td>
<td>Shovels/Cranes (Tracked)</td>
<td>60.00</td>
<td>28.00</td>
</tr>
<tr>
<td>902/3</td>
<td>Ruskin Bucyrus 22, Koehring</td>
<td>60.00</td>
<td>28.00</td>
</tr>
<tr>
<td>903</td>
<td>Rollers (Motor)</td>
<td>34.00</td>
<td>16.00</td>
</tr>
<tr>
<td>903/1</td>
<td>Awaling-Barford 21 3/4 ton Steel-Tyre</td>
<td>34.00</td>
<td>16.00</td>
</tr>
<tr>
<td>903/2</td>
<td>Awaling-Barford 6/8/10 ton Steel-Tyre</td>
<td>48.00</td>
<td>24.00</td>
</tr>
<tr>
<td>903/3</td>
<td>Gallon, Awaling-Barford, Huger 12/15 ton Rubber-Tyre</td>
<td>68.00</td>
<td>34.00</td>
</tr>
<tr>
<td>903/5</td>
<td>Wakefield 5/12 ton</td>
<td>44.00</td>
<td>22.00</td>
</tr>
<tr>
<td>903/6</td>
<td>Gallon Rubber-Tyre</td>
<td>68.00</td>
<td>34.00</td>
</tr>
<tr>
<td>903/7</td>
<td>Gallon Vibrating, Lautenhausen</td>
<td>30.00</td>
<td>15.00</td>
</tr>
<tr>
<td>903/8</td>
<td>Compactor 818 CAT</td>
<td>26.00</td>
<td>13.00</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Group</th>
<th>Equipment</th>
<th>Hour Rate</th>
<th>Day Rate</th>
</tr>
</thead>
<tbody>
<tr>
<td>904</td>
<td>Dumpers &amp; Loaders (Wheeled)</td>
<td>36.00</td>
<td></td>
</tr>
<tr>
<td>904/1</td>
<td>Benford &amp; Barford Dumpers</td>
<td>36.00</td>
<td></td>
</tr>
<tr>
<td>904/2</td>
<td>Massey-Ferguson 3305/3165</td>
<td>66.00</td>
<td></td>
</tr>
<tr>
<td>904/5</td>
<td>CAT 944, 920, A.B. 230 Loader</td>
<td>30.00</td>
<td>15.00</td>
</tr>
<tr>
<td>904/7</td>
<td>F.E.L CAT 850</td>
<td>28.50</td>
<td>14.25</td>
</tr>
<tr>
<td>904/6</td>
<td>CAT 966C F.E.L</td>
<td>30.00</td>
<td>15.00</td>
</tr>
<tr>
<td>904/8</td>
<td>CAT 960B F.E.L</td>
<td>31.50</td>
<td>15.75</td>
</tr>
<tr>
<td>905</td>
<td>Dump Truck</td>
<td>80.00</td>
<td></td>
</tr>
<tr>
<td>905/5</td>
<td>Dump Truck</td>
<td>80.00</td>
<td></td>
</tr>
<tr>
<td>906</td>
<td>Cranes (Vehicle Mounted)</td>
<td>66.00</td>
<td></td>
</tr>
<tr>
<td>906/1</td>
<td>Coles Hydra Speed S.W.L. St.</td>
<td>33.00</td>
<td>16.50</td>
</tr>
<tr>
<td>906/2</td>
<td>Coles Arga S.W.L. St.</td>
<td>62.00</td>
<td>31.00</td>
</tr>
<tr>
<td>906/3</td>
<td>Coles Hydra Husky, Osborn</td>
<td>58.00</td>
<td>29.00</td>
</tr>
<tr>
<td>906/4</td>
<td>Koehring S.W.L. 30L</td>
<td>80.00</td>
<td>40.00</td>
</tr>
<tr>
<td>906/5</td>
<td>Boom Truck, White Star</td>
<td>1.55</td>
<td>80.00</td>
</tr>
</tbody>
</table>

*For hourly only or part thereof, up to maximum daily rate subject to minimum daily charge.*

Source: Plant & Vehicle Hire Organization Government of Malawi, 1-4-82.
gets due to severe general financial pressures on governments simultaneously with sharp price inflation has led in recent years to the breakdown of many equipment hire schemes, some of which were long and successfully established.

5.12 Many developing country governments, under severe financial pressures, have simply chosen to ignore the costs of equipment depreciation, choosing to consume assets without provision for replenishment. In situations of extreme short-term stress this policy is rational, since it is better to utilize whatever budget is available to effect some utilization of the existing assets, rather than claim much of the limited budget for depreciation with the consequence that the equipment sits idle most of the year for want of operating budget. But this course is obviously short-lived, necessarily ending when the assets in hand are all consumed. Replenishment then awaits refunding from the general exchequer or a foreign donation, either of which are typically sporadic, and in the meantime equipment users must limp along with overaged equipment, high downtimes, and increasingly costly maintenance — costs which ultimately may cumulate to much more than the costs of earlier replacement.

5.13 Proper recognition and budgeting for the full costs of equipment are essential steps toward effecting the much improved utilization of equipment fleets which should ultimately generate major economies, which would in turn contribute much to easing the overall financial burden. A substantial injection of capital may initially be required to renew the equipment fleet, replenish inventories of spare parts and restore a reasonable balance of working capital. This injection of capital may be seen as an appropriate focus of World Bank aid, or other foreign assistance. But this aid should be conditioned on government acceptance that the depreciation and interest on those assets constitutes a recurrent cost which must be explicitly recognized, budgeted, and accounted for.

5.14 Recognition and budgeting for these costs is not, however, a sufficient condition to ensure efficiency. There must be incentives for the equipment user to effect economies in accordance with the recognized costs. At a minimum, any savings in equipment costs should be fungible to the individual manager for use in other ways to meet his unit's objectives. Recognition should be afforded to those who are more efficient, and ideally some form of cash rewards would be introduced, as has been the case in the United Kingdom12/ and Yugoslavia13/ road authorities in recent years.

12/ Brian E. Cox, "Evaluation of the U.K. System of Incentives for Efficiency in Road Maintenance Organizations and Possible Lessons for Developing Countries" (World Bank Transportation Department, forthcoming).

5.15 The control over funds accumulated from depreciation charges should be left solely in the hands of the equipment agency for use in the regular replacement of the fleet and replenishment of spare parts inventories, while the equipment agency would in turn be expected to pay an interest charge. Less desirably, the Treasury could still retain the right to block usage of the depreciation reserve funds, when and if it deemed necessary, or to require import licences which it controls. In any case it may still wish to employ foreign loans or credits as the appropriate source of foreign exchange, but the key elements — explicit recognition and budgeting for full costs and regular renewal of the fleet — must be retained, if any substantive improvements in efficiency are to be achieved.

5.16 These arrangements could be affected through the accounts of the road authority itself, but establishment of the equipment agency as a formal hire-funding entity may often facilitate matters. In some cases establishment of the equipment agency as a parastatal entity could, if properly effected, provide important advantages in personnel management (salaries, hiring and firing) so as to attract, retain and motivate abler staff, and in freedom from encumbering bureaucratic restrictions. It could also facilitate establishment of cost-accounting and pricing in accordance with commercial practices, so that full costs would be more readily recognized.

5.17 Safeguards would have to be incorporated to ensure that existing inefficiencies were not merely reincarnated in the form of continuing public subsidies, as is all too frequently the case with parastatal entities in other sectors. But it is a distinct advantage of the parastatal versus a normal governmental organization that the performance of the agency can more easily be evaluated and compared with that of alternative private suppliers. Provision should be made that the agency compete (on a comparable basis) with private suppliers, and its scope, indeed its continued existence, would be determined in the market place. Such a system, which has been in effect in the United Kingdom since April 1981, is already credited with marked improvements in efficiency, and the road authorities are reported to have found that many items of equipment are more economically obtained on hire from the private sector (Cox, 1984). In countries where the private construction and equipment markets are less well developed than in the United Kingdom, implementation of such a system would evolve more slowly, but once it became evident that market opportunities with a stable, long-term demand were available, private suppliers, very possibly with support from the equipment manufacturers themselves, could be expected to come forth.
VI. Equipment Management Improvement Plans

A. Introduction

6.01 The principles of effective and efficient equipment operation are the same anywhere, but the action required to achieve acceptable standards will vary from country to country. An Equipment Management Improvement Plan (EMIP) is therefore required to set out both the general principles and the specific steps required for each particular case.

6.02 Some necessary actions are easily identified and easily taken, while others are more difficult and require additional resources or fundamental organizational and motivational change. Where substantial change is required—and, unfortunately, the evidence suggests this is the majority of cases—a strategic choice must first be made between a policy of gradual change in a series of marginal steps over time, or a more abrupt change, i.e., converting immediately to a comprehensive new system. Typically management consultancies have favored the latter, since their comparative advantage is in working with the systems they know best, i.e., their own, and they normally know little of their client's existing systems. However, this can place a very heavy burden on the client authority's staff, who are likely to be even less suited to mastering new systems, and it should not be surprising that the introduction of holistic new management systems has so often failed. Wherever an existing equipment management system offers at least the fragments of a workable system, serious consideration should be given to the marginalist approach of improving the existing system, rather than supplanting it entirely.

6.03 Whichever strategy is pursued, and even if consultants are required to formulate and initiate the implementation of an EMIP, the emphasis must be placed from the beginning on developing and motivating local staff to put things right for themselves, step-by-step, within the guidelines of the plan. Every aspect of the plan—the strategy, substance, and time scale for each step—needs to be thoroughly discussed with local staff concerned, and the widest possible consensus achieved. Where full consensus is not possible, specific ways to deal with anticipated opposition must be devised. Many efforts to improve the performance of equipment departments in the past have failed because of failure to mollify impacts on those who perceive their vital interests, legitimate or otherwise, to be threatened.

6.04 The overall objective of an Equipment Management Improvement Plan is to achieve an "optimum" balance between rejuvenating, developing and matching the available and obtainable new resources to the operational requirement, and limiting the requirement to the feasible resources. Substantial improvements in the efficiency of utilization of existing resources should normally be possible, and are a primary objective of the EMIP. Scraping of non-economic items of equipment and proper rehabilitation of the salvageable items of the existing fleet is the appropriate place to begin. Even greater gains can be achieved through improvements in management systems, and introduction (or enhancement) of incentives for efficiency are of critical
importance. Upgrading of human resources through training and reorientation toward accountability and achievement of efficiency objectives is also an important step. With this multi-faceted approach, the amount of new equipment required may be greatly reduced, and costs contained.

6.05 In preparing an EMIP the first step, therefore, is to assess the existing and potential resources of the equipment department, to see how effectively and efficiently they are currently being utilized, to compare them with the resources required to meet the work requirement, and to make recommendations to bridge the gap. The second step is to review the organization, policies, procedures, and individual as well as collective motivation at different levels, and to identify possible improvements. The third step is the preparation in collaboration with local staff of the specific Equipment Management Improvement Plan detailing and programming the changes recommended. The various aspects of those assessments and procedures proposed for executing them are discussed in the following paragraphs. Terms of reference for consultants or for the guidance of a department's own staff doing this work are given in Annex 6.1.

B. Scope

6.06 The scope of the survey is shown below where the five main subjects or functions of the department and the various aspects to be assessed for each subject are listed below. Recommendations must be made in respect of each aspect which is unsatisfactory or for which changes are required.

<table>
<thead>
<tr>
<th>Subjects to be Assessed</th>
<th>Aspects of Assessments of Each</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Equipment fleet holdings, utilization and management</td>
<td>1. Existing situation</td>
</tr>
<tr>
<td>2. Fleet size, suitability and replacement policies</td>
<td>a) Policy objectives and motivation</td>
</tr>
<tr>
<td>3. Equipment maintenance</td>
<td>b) Organization and procedures</td>
</tr>
<tr>
<td>4. Supplies and spare parts</td>
<td>c) Audit and accountability</td>
</tr>
<tr>
<td>5. Finance, accounting and administration</td>
<td>d) Suitability (Quality and Quantity)</td>
</tr>
<tr>
<td>6. Staff abilities and motivation (workforce and management)</td>
<td>e) Effectiveness/utilization</td>
</tr>
<tr>
<td></td>
<td>f) Efficiency/cost</td>
</tr>
<tr>
<td></td>
<td>g) Legal and safety requirements</td>
</tr>
</tbody>
</table>

2. Existing situation vs. present and future requirements.

3. Recommendations (plan for next five years)
C. Equipment Fleet Holdings, Utilization, and Management

6.07 **Inventory and inspection of existing fleet holdings.** An audit and inspection of all major items of powered equipment with a replacement value of more than, say, US$1,000, must be made and, if possible, verified with the plant inventory or assets register. Equipment should be classified by type, capacity, make, model, age, location and condition. Condition should be expressed in terms of approximate remaining economic life and recommendations made concerning which items should be scrapped and which rehabilitated, as specified in Annex 6.1. Ultimately, this initial assessment may have to be revised in light of subsequent assessment of maintenance, replacement and standardization policies, and resource constraints, but an inventory and initial quick assessment is an essential first step.

6.08 **Fleet utilization and management.** An examination of the type, capacity, quality and suitability, of the existing equipment for the work required, its reliability/availability and utilization, is the next step. As utilization is the key indicator of the effectiveness of the entire equipment operation, particular care should be taken to verify, if possible, the reported hours of utilization. Cross-checks should be made against claimed quantities of work, output achieved, amount of fuel and spare parts used, etc., and significant discrepancies between reported availability and utilization must be explained. Where such data are fragmentary, suspect, or are simply not available, an educated guess must be made to assess both existing utilization and potential improvements.

6.09 Where utilization of major items of equipment is below reasonable norms (e.g., 1200 hours p.a. in maintenance operations), an assessment must be made of the various constraining factors. Figure 6.1 provides a step-by-step diagnostic diagram. The first step is to determine whether there is high availability; if availability is high and utilization is low, it can be presumed that the constraining factors lie in the area of field management (e.g., inadequate incentives to field managers and staff for efficient utilization, or an oversupply of equipment in relation to needs, or inadequate supplies of fuel and other complementary resources). Where availability is low, the problem presumably lies within the mechanical branch—inefficiencies in the supply of spare parts; the number, skill and motivation of mechanics; and/or workshop management (see section E below)—or in the age and composition of the fleet, which may in turn be related to inappropriate equipment, costing, pricing, budgeting, and replacement policies.

6.10 Organization and procedures at every level should be evaluated with particular attention to factors which militate for or against deficiency of utilization, e.g., to what extent are managers and lower level staff held accountable for performance, to what extent do savings in equipment costs accrue to the user's unit for other uses (perhaps partly in bonuses to staff), and to what extent are the full costs of ownership (depreciation at replacement prices, plus interest) reflected in the budget planning?
FIGURE 6.1 - EQUIPMENT UTILIZATION PROBLEMS - DIAGNOSTIC DIAGRAM

A flowchart showing the equipment utilization problems and diagnostic diagram.

1. **Equipment Fleet** larger than needed?
   - Reduce future replacement; use redundant fleet as source of spares or rentals.

2. **Suppliers of fuel, bitumen, etc.** inadequate?
   - Seek adjustments in recurrent cost funding to balance with capital funding.

3. **Inadequate staff training** too few staff?
   - Skill management
     - Operators
     - Workshop management
     - Mechanics
   - Evaluate manpower planning and training and recommend improvements.
   - Where less of staff to private sector is high, scale-up training programs commercially and identify measures for enhancing appeal of public service.

4. **Incentives for efficient maintenance** inadequate?
   - Equipment under-priced or budget charge irrelevant?
   - Personal incentives to staff and/or labor inadequate or negative?
   - Change costing and budget procedures, making savings fungible to the user’s unit, creating profit centers on commercially competitive basis, with retention of at least some profits for staff bonuses.
   - Enhance accountability with positive and negative incentives, linking bonuses to individual and collective performance, with penalties for poor performance.

5. **Management information systems** inadequate?
   - Improve management information systems, train personnel and enforce implementation.

6. **Spares parts supply** inadequate?
   - Poor inventory management? (prediction of requirements, stock control, warehousing and distribution).
   - Heterogeneous fleet with many makes and ages, no standardization?
   - Cumbercumbersome procurement policies with clearance required from many different individuals or multiple agencies (e.g. tender boards, foreign exchange license).
   - Budgets inadequate (local currency, foreign exchange, or both) end/or government tariffs in paying bills reduce supplier willingness to grant credit.
   - Analyze benefits from standardization and recommended basing for taking these benefits into account in future equipment tenders.
   - Trace complete chain of events from initial identification of spares tender through procurement of order, shipment, customs clearance and delivery to workshops. Identify and discuss possible streamlining at interministerial level if need be.

1) Seek adjustments in recurrent foreign exchange budgeting.
2) Ensure ample financial provisions for spares in any procurement of new equipment to be purchased in tranches as needs are identified.

A scheme, under the scheme, ideally on a self-financing basis, is desirable if feasible. In some cases the conversion of government direct labor organizations into private or private enterprises may be the only means to bring about more competitive salaries, greater incentives for efficiency (including recognition of the full costs of equipment and avoidance of unwieldy bureaucratic procedures. Possibilities for contracting out various functions, in whole or part, should also be considered.
D. Fleet Size, Suitability and Replacement Policies

6.11 An examination of the suitability of the fleet holdings to meet present and future needs is the next step. This must be done in cooperation with the equipment users, i.e., the road maintenance and construction engineers. Factors to be considered include the type, capacity, quality, and quantity of all major items of equipment in relation to forecast work requirements taking into account the improvements in availability, utilization and productivity which can reasonably be anticipated.

6.12 Typically, existing fleet holdings will be an amalgam of different ages and makes accumulated over the years for diverse purposes, often not suited to present or future requirements, and often so heterogenous as to pose excessive requirements for spare parts inventories. The equipment users should clarify the principal work requirements and, in conjunction with the mechanical department, identify the most appropriate equipment. Wherever feasible, standardization in future tenders on a few more fungible makes and models should be evaluated in accordance with Chapter IV.

6.13 The timing of replacement should ideally optimize the tradeoffs between anticipated future maintenance of existing equipment, its lower availability and productivity, and the capital costs of new equipment with its anticipated higher availability and productivity. These relationships have been discussed in Chapter IV. In many cases the data to quantify these tradeoff relationships will not be available from existing management information systems, and educated guesses will be necessary in the first instance. Often, also the actual timing of replacement will be constrained by the availability of finance, but it should be recognized that failure to replace overaged equipment ultimately inflicts much higher costs—in terms both of excessive spare parts and mechanic's time in maintenance efforts and in the disruption of work due to excessive downtime.

6.14 The equipment requirement over the next five years should be quantified, first in terms of hours of work required for the different classes of equipment, and then in terms of numbers of equipment taking into account existing and forecast equipment availability, utilization and productivity. Target utilization figures should be recommended for the different classes of equipment. (As a very rough guide, 1250 hours per annum for major items of equipment in maintenance work would be a realistic average to aim for in many departments, but each case would need to be judged on its merits).

6.15 Comparison of the anticipated requirement over the next five years with the available equipment will enable surpluses and deficits to be established and, allowing for the replacement of existing equipment when it reaches the end of its economic life, recommendations can be made for equipment requirements over the next five years and a procurement schedule drawn up spreading out the purchase as evenly as practicable over each of the years.
E. Equipment Maintenance

6.16 The existing maintenance policy should be examined with regard to its overall effectiveness and efficiency, including the balance of preventive to corrective maintenance, and the role of mobile workshops relative to fixed facilities. The use of the private sector should be considered for any of the equipment maintenance work wherever this might yield more effective and/or more efficient service.

6.17 In examining the organization of mechanical support services, the first issue to be considered is the appropriate role of mobile workshops; often inadequate provision is made for mobile workshops, which, when properly equipped and staffed, can effect a wide range of equipment repairs in the field and greatly reduce time lost in transporting unserviceable equipment to and from fixed facilities. Next to be considered are the location and organization of the fixed workshops. For all workshops, staff and procedures should be evaluated and an audit taken of space, floor layouts, parts inventories, tools, and equipment. The suitability and utilization of the workshops and maintenance procedures should be considered and their effectiveness assessed. Equipment availability, or downtime, is the key overall indicator of the effectiveness of the equipment maintenance branch: time awaiting spares' should be noted and netted out, as this will be considered in evaluating the efficacy of the supplies branch.

6.18 The efficiency of the maintenance carried out will be indicated by the maintenance cost, by the ratio of maintenance branch overheads to the direct cost of productive labor, and by the ratio of maintenance work required for the correction of previous maintenance errors to the cost of all the maintenance work. Where standard times are fixed or known for some of the maintenance tasks, a comparison can be made with actual times taken.

6.19 There should be a system of periodic inspection of equipment as part of the preventive maintenance system, and of inspection of equipment before and after maintenance repair work as part of the workshop's quality control system. These need to be checked and assessed. Where the equipment fleet constitutes a sizeable investment, consideration should be given to the introduction of advanced systems of oil spectrographic analyses for regular monitoring of equipment condition and determination of preventive maintenance needs.

6.20 Legal and safety requirements are often specified by law, and in any case a record of accidents, tests on potentially dangerous items of equipment (e.g. lifting equipment and air receivers) should be kept and checked.

6.21 The equipment maintenance requirement should be assessed for the next five years in terms of working space, tools, equipment, procedures and staff on a geographical basis, and compared with the present capability. Recommendations should be made to account for the difference and to cover the improvement of all other aspects of maintenance reviewed above.
6.22 The procurement and stocking policy should be examined. Most departments compromise between the two extremes of either importing directly and stocking departmentally, or of relying completely on local agents. The best economic balance should be sought. The extent to which purchasing policy is dictated by the Treasury or a Government Central Stores Organization or Tender Boards should be considered together with the resulting procedures and the delays and constraints these impose on supplies staff.

6.23 The organization of the stores and the degree of centralization or autonomy of district or regional stores should be reviewed. Internal procedures should be examined, particularly with regard to stock control and the use of re-order quantities and re-order levels. A stock check must be carried out on a representative sample of the spare parts, tires, fuel, and note taken of discrepancies, and the dates and magnitude of previous stock checks. The level of stock and the value of redundant spares must be estimated, and any appropriate action for disposal recommended. Where significant stocks are held at the district or regional level, up to date information as to stock availabilities at each level should be available at a central information bank.

6.24 The suitability of the stores buildings, and the storage, binning, preservation, identification, and selection of spares and stores for stock must be evaluated.

6.25 The effectiveness of the supplies service must be assessed. Key indicators are the number and value of equipment awaiting spares each week and the average length of time awaiting spares. The service levels (line items supplied without delay divided by total line items demanded each month, and the ratio of emergency orders to stock orders) are also appropriate indicators.

6.26 The efficiency of the supplies service must also be assessed, and the cost of providing the service should be considered in terms of the on-cost for handling charges and overheads related to the value of the stock being issued, and in terms of the total cost of the spare parts supply service for a year to the value of the fleet owned and to the cost of equipment downtime. Turnover of stock (total value of issues per annum to average value of stock held) and the ratio of the value of redundant stock held to the total value, the value of redundant spares written off annually to the total value of spares issued, number of line items issued per employee in the supplies service, and value of losses to the value of turnover will give a further indication. Some dealers are prepared to commit themselves to provide a specified level of availability of spare parts.

6.27 The required level of investment in the supplies system over the next five years should be estimated and justified economically, as discussed in Chapter III. Recommendations should be made to meet this requirement.
6.28 Compliance with legal requirements and safety precautions should be checked (e.g., the storage and handling of inflammable stores).

G. Finance and Administration

6.29 The total costs of owning and operating the equipment fleet by type of expenditure per annum, by the cost per hour worked or kilometer run for individual items of equipment, and average costs for the various classes or types of equipment must, where they exist, be examined and verified, as these costs are key indicators to the efficiency of the equipment department as a whole.

6.30 Copies of the last five annual reports (where available) or appropriate extracts therefrom should be reviewed and included in the assessment section of the plan. The use and accuracy of any existing costing system should be assessed and, while a detailed description is not required, it should be compared with the proposals made in the Crown Agent's report (Eaton, 1984) and comment made on strengths, weaknesses and possible improvements.

6.31 Policies for provision and control of funds must be considered and the advantages of a revenue-producing hiring scheme assessed, if this is not already in existence; see Chapter V. If it exists, the degree of autonomy in deciding hiring rates and spending of revenue must be examined. The organization and procedures of the financial and administrative branches and procedures used including auditing procedures, should be evaluated.

6.32 The adequacy of the funds requested and allocated, and the basis of budget forecasts must be assessed. Expenditures and the financial and cost accounting systems should be examined. Monthly and annual statements of costs and accounts should be accurate, timely and presented in a way which can be easily understood by all levels of management.

6.33 Past and future economy measures should be considered particularly with respect to saving foreign currency. Typically, three-quarters of the cost of utilizing equipment may involve foreign currency. Reductions in the size of the fleet by improved utilization, and careful use of tires and fuel offer the biggest economies, and these should be considered. The effectiveness of the overall equipment branch should be considered, and its cost and numbers of staff related to the total cost of the equipment fleet, the total number of staff in the department, and the number of productive staff.

6.34 Funds required by the equipment department for the next five years should be budgeted under separate headings, including one for the purchase of equipment.
H. Staffing

6.35 Staff policies and conditions of service should be examined with particular reference to rates of pay (and their effect on recruitment and staff turnover) and to disciplinary and motivational procedures (their application and their effect on staff productivity). These are vital matters, since it is not possible to run the department efficiently unless suitable staff can be retained, motivated, and controlled.

6.36 A staff audit is required for all grades and the suitability of the staff must be assessed in terms of quality and quantity. The effectiveness and efficiency of the staff must be assessed at all levels, but should be grouped for convenience under headings of Workforce and Management. Effectiveness should be assessed on the basis of doing what is required properly and at the time it is required. The efficiency of the staff must be assessed and will take into account the productivity of staff directly employed on the job and the ratio of productive staff to the total number of all staff employed. Rates charged (including overhead costs) for operating and maintaining equipment must be examined and time taken to do sample jobs assessed.

6.37 Management staff should be considered separately from the workforce, and they should include all staff responsible for the work of others. The policies affecting management must be considered. The organization of management staff and procedures used, where these are not adequately covered under the foregoing departmental headings, must be reviewed. An audit of existing management staff must be made. An assessment of their suitability must be made in terms of knowledge and experience of the work being supervised, degree of interest and involvement in the job, ability to get others to work satisfactorily, and any significant difficulties in this area, whether management is in control of the job or vice versa, whether the general situation is getting better, worse, or is static, and whether management is aware of the trend. The information sought by and made available to management, and action taken in consequence, must be reviewed. The style of management practiced, and the way the workforce is organized, motivated, instructed, supervised, trained and developed must be examined. The cost of providing management must be assessed in relation to the workforce.

6.38 Staff requirements for the next five years must be forecast and compared with available staff. A program for training and recruitment or transfer of staff must be drawn up to match the resource to the requirement. Factors affecting the efficiency of the workforce must be examined. In addition to training and ability, motivational and behavioral problems must be considered and appropriate recommendations made.

6.39 The requirement for management staff over the next five years must be assessed and compared with the available staff position. Recommendations must be made on how the requirement should be met including the selection, promotion, training and development of supervisors and managers. Recommendations must be made for the improvement of management methods. Job descriptions with key objectives, tasks and targets, should be compiled, and a management information system recommended to facilitate the regular appraisal of the performance of management staff.
6.40 Targets should be set which are within the reach of the staff. Targets set will obviously vary with local situations but an average utilization of equipment would probably be 100 hours per month. A ten percent improvement in the previous year's performance is a modest target to aim for initially. The use of incentives and motivation of staff by a greater participation in decision taking, and the setting of targets, must be carefully considered.

6.41 Finally, recommendations covering the next five years should be phased for implementation at a rate which permits changes to be digested and absorbed permanently into the system.


7. V. D. Johnston, "Guidelines for Plant Management", report prepared for Main Roads Department, Western Australia (c 1982).

8. J. J. Harvey et al, "A Plant Information and Reporting System", report prepared for Main Roads Department, Western Australia (c. 1982).

ANNEX 2.1

**Definition of Terms**

The five key terms used in Stage 1 are defined below:

(a) **Normal working hours** - this is the normal number of working hours in a given period of time, usually a month or a year, and is the base against which equipment availability and use is measured. It is common practice that mealtimes, overtime, weekends and public holidays should be excluded when calculating normal working hours.

(b) **Idle time** - this is the time in hours during the normal working hours when equipment is serviceable but not worked for whatever reason.

(c) **Unserviceable** - this is the time during which equipment is unserviceable, such as being broken down, awaiting repairs, under repair or being serviced. It may be expressed as a percentage of normal working hours but the actual number of the normal working or base hours must be shown.

(d) **Availability** - this is the time during the normal working hours when the equipment is available for use or being used. Normal working hours less hours unserviceable equals availability in hours. This may also be expressed as a percentage of normal working hours, but again the normal working or base hours must be indicated.

(e) **Utilization** - for plant this is the time in hours that the equipment is working. For vehicles the distance run is used as an indication of work done. While distance run cannot be expressed as a utilization percentage, this is not a drawback as the distance travelled per day or per month is usually the best indication of the use made of vehicles. Thus, it is essential that vehicle speedometers be repaired or replaced promptly, but if they become unserviceable, an estimate of distance run can be made from the fuel consumption.
ANNEX 2.2

Stage I – Management Information Reports and Worksheets

1. The information requirement of this stage is the submission of two monthly and two annual reports as described below. Sample report forms and worksheets are shown at the end of this Annex.

(a) Monthly Equipment Availability and Utilization Report (Form 1)

This would be submitted for each item of powered road maintenance equipment by each region or control center. The items should be arranged in classes with totals and averages shown for each class. A monthly summary of the regional reports for the whole equipment fleet to give fleet totals by class would be prepared at the equipment department headquarters, and at the end of the year the same report sheet would be used to show annual totals by class for hours worked or kilometers run for each of the regions and average class availability for the year. Column 1 of the report, headed “Class of Equipment” should be a simple classification of equipment with graders, dozers, rollers, etc., being kept together in their own groups and subdivided if required for the convenience of the department e.g., where subdivisions or classes already exist. Items in any one class should be in fleet number and hence chronological order. Column 2 would show briefly the make and or type of equipment, e.g., D7 will do for a Caterpillar D7 tractor.

Entries in columns 1 and 2 need to be made only for the first entry of each class or type. Column 3 shows the fleet number where the entry is for one item of equipment, or the number of items in the class when the line shows a class total. Column 4 shows hours unserviceable during the month and column 5 gives a year-to-date (YTD) total.

Fuel used in column 10 shows the total amount of fuel issued during the month. Equipment fuel tanks should be filled wherever possible each time refuelling takes place but particularly on the last working day of each month and speedometer and hourmeter readings taken. The fuel used is required to check on hours worked, and where the hourmeter is not working, to derive hours worked. The average rate of consumption for the month is shown in Column 11. For motor vehicles only, the international convention of showing consumption in liters per 100 kilometers is suggested.

(b) Monthly Report on Unserviceable Equipment (Form 2)

This report is submitted by each region or control center at the end of each month and shows which of the items of equipment unserviceable at the end of the month had been unserviceable (u/s)
for more than 14 days, the date on which it became unserviceable (Col. 4) and the estimated date that the equipment will be back in service (Col. 7). In column 6 "Action Taken", it is important to show the situation, e.g., work in hand, awaiting labor, awaiting write-off, or awaiting spares in which case the spares requisition or order number and the date should be shown.

This form should be prepared by workshop staff and comment made in column 8 on order numbers, and progressing of spares by stores staff where appropriate. Information regarding dates unserviceable and back into service should be available from workshop progress and planning chart or the workshops job cards (form C or D).

(c) Annual Equipment Audit Report (Form 3)
This report, which is self-explanatory, shows the equipment owned and whether the quantities in the various classes increased or decreased during the year. It also shows how many items of each class were allocated to each region at the end of the year. It summarizes the allocations shown on the "Monthly Equipment Availability and Utilization Report (Form 1). It also shows how many items of each class were allocated to each region at the end of the year.

(d) Annual Staff Audit Report (Form 4)
This report serves three purposes. It shows the actual strength and location of all grades of staff at the end of the year and the authorized establishment. It shows the staff at the beginning of the year and losses and gains during the year enabling an annual turnover to be seen. It also shows the number of staff promoted and what training was carried out during the year.

**Stage 1 - Suggested Source Data Reports and Worksheets**

2. The following forms are suggested for compilation of the source data needed to prepare the Stage I management information reports (Part A) and also to aid in the control and management of operations at the subordinate levels where they are prepared.

(a) Daily Fuel Receipt and Issues Sheet (Form A)
This supports Form 1 and records daily issues of fuel and lubricating oil against individual items of equipment. The tank or tanks on the equipment should be filled fully and the hourmeter or speedometer reading recorded at the time. Every effort should be made to fill up all equipment on the last day of each month. Columns are provided to record the quantities and types of lubricating oil issued. This is not part of the Stage 1 requirement but it will be of use to workshops and stores staff.
Each bulk fuel storage tank or tanker should have its own sheet or sheets. The information at the top of the sheet is to provide strict accountability. The opening dip means the quantity in the tank or tanker at the beginning of the day according to the dipstick. This is a good guide but may only be accurate to the nearest five or ten gallons depending on the calibration of the dipstick. A dip should always be taken to verify the quantity of any fuel supplied to the tank or tanker and the quantity is entered against fuel added. The quantity indicated on the closing dip at the end of the day, when subtracted from the total of the opening dip and fuel added, indicates the day's usage or issues according to the dipstick. The usage (meter) on the right hand side of the form shows the usage for the day according to the meter by subtracting the opening meter reading from the closing reading. The usage (sheet) is the total quantity issued according to the amounts booked out on the sheet. The three usage figures (dip, meter and sheet) should be in approximate agreement. The "hours/kms" column shows the hourmeter of speedometer reading at the time an issue of fuel is made to the equipment.

(b) Monthly Utilization, Fuel and Unserviceability Record (Form B)
This form records the daily entries made on Form A for each item of equipment to enable monthly totals to be obtained for use with Form 1. It also records time under repair or hours unserviceable to enable monthly totals to be obtained. Time unserviceable may be obtained either from the workshops job cards or maintenance progress planning charts described below (Forms C and D).

(c) Monthly Workshop Equipment Maintenance Progress and Planning Chart (Form C)
This chart should be displayed on a wall in the workshop. The columns numbered 1 to 31 represent the days of the month and an entry in these columns indicates work in progress (P), awaiting labor (A/L), awaiting spares (A/S), etc. Planning of future work can be done by using symbols such as AD, AB and DC for A, B and C services due and AC, BC and CC for the same services completed. AD and AC should normally appear in the same square for the A service in question if it is carried out on the date it was due, but if it is carried out late, the AD and AC will appear in different squares according to their respective dates. This enables arrears of planned maintenance to be seen at a glance. The use of the symbols is described on the form.

At the end of the month, the chart should be left on the wall and a chart for the following month placed alongside or on top of the old one so that reference can be made back for previous history.

(d) Workshops Job Cards (Form D)
The use of job cards is fairly common and the card suggested here needs little explanation. It describes and authorizes the work
required and records the work done, and the cost of workshops labor and spare parts used. The terms "preventive" and "corrective" refer to the type of maintenance carried out. The objective of splitting maintenance into two main divisions is twofold. It enables the cost to be seen of work which should not have been necessary arising from accident, misuse, neglect, or premature failure. This is designated "corrective" maintenance. It also enables a check to be kept on the cost of servicing and maintenance work arising through fair wear and carried out to prevent breakdown. This is designated "preventive" maintenance the cost of which needs to be kept to a minimum compatible with the avoidance of imminent breakdown. The ratio of preventive to corrective maintenance is important as it indicates whether the most economic mix of the two is being obtained. It is important not to pay too high a price in an effort to avoid all breakdowns, e.g., the overall cost of an occasional breakdown (say a half shaft failure) would not justify changing all the half shafts to completely eliminate this possibility. It is better to tolerate occasional breakdowns in such circumstances. Whilst the cost of one type of maintenance can easily be minimized at the expense of the other the lowest combined minimum cost should be sought and for motor vehicles experience in some countries indicates that this occurs when, on average, the ratio at preventive to corrective maintenance is about two to one. However, all ratios of this type need to be verified under local conditions. Common sense must prevail at the consequential costs of breakdown for an asphalt plant which could prevent many tippers and road maintenance staff from working are obviously greater than those of a single motor vehicle. "Mod" at the end of the third line stands for modification as it is sometimes necessary to modify equipment to meet local conditions. In ticking off on the job card the type of work to be done, accident, breakdown and warranty work should also be ticked and charged as corrective and modification work as "preventive". Credits for warranty work should be credited to corrective maintenance.

Where and how job cards are kept will depend on the way the workshop is organized. Three copies are likely to be required; one for workshops control, one for the section undertaking the work, and one for the stores to facilitate the recording details and cost of spares issued. Placement of job cards in the section either by hanging on the wall or placing in slots is recommended. The slots should be grouped to indicate the various stages of progress or delay and the job cards placed in appropriate slots, e.g., work not started, started but awaiting labor, awaiting spares, in progress, awaiting test, awaiting collection. The "awaiting spares" group of slots may be divided into subgroups, e.g., awaiting spares for more than 1 week, 2 weeks, 3 weeks, 1 month, 2 months, etc.

(e) Workshops Job Book (Sample Page, Form E)
A job book or register is required to record and control the issue of job cards which should be recorded in serial number order. The suggested form is self-explanatory.
### Daily Fuel Receipt and Issues Sheet

<table>
<thead>
<tr>
<th>Location</th>
<th>Type of Fuel</th>
<th>Capacity of Tank</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Pump/Tanker No.</th>
<th>Opening Dip</th>
<th>Fuel Added</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Closing Dip</th>
<th>Usage Dip</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Equip. Class</th>
<th>Fleet No. issued</th>
<th>Liters</th>
<th>Hours/ kms</th>
<th>Equip. Class</th>
<th>Fleet No. issued</th>
<th>Liters</th>
<th>Hours/ kms</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Totals</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
</tr>
</tbody>
</table>

Fuel issued by ____________________________

Checked by ____________________________

Posted to summary by ____________________________
### Monthly Utilization Fuel and Serviceability Record for

**Class:** [Class Name]  
**Fleet No.:** [Fleet Number]

<table>
<thead>
<tr>
<th>Date Issued</th>
<th>Fuel reading u/s</th>
<th>Hours/km b/f</th>
<th>Hours u/s b/f</th>
<th>Date Issued</th>
<th>Fuel reading u/s</th>
<th>Hours/km c/f</th>
<th>Hours u/s c/f</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Date Issued</th>
<th>Fuel reading u/s</th>
<th>Hours/km b/f</th>
<th>Hours u/s b/f</th>
<th>Date Issued</th>
<th>Fuel reading u/s</th>
<th>Hours/km c/f</th>
<th>Hours u/s c/f</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Compiled by [Name]  
Checked by [Name]
# ANNEX 2.2

## FORM C

Workshop Equipment Progress and Planning Chart

<table>
<thead>
<tr>
<th>Region</th>
<th>Month</th>
<th>Workshops</th>
</tr>
</thead>
</table>

List each item of equipment maintained by workshops in class order.

| Class | Type | Fleet No. | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 | 25 | 26 | 27 | 28 | 29 | 30 | 31 |
|-------|------|-----------|---|---|---|---|---|---|---|---|---|----|---|----|---|----|---|----|---|----|---|----|---|----|---|----|---|----|---|----|---|

This sheet is illustrated at half full size.

Suggested symbols: A, B, C indicate A B & C type services. The suffices C & D indicate "completed" and "due"

e.g. AD = A service due; AC = A service completed.
S/ar = Spares all received.
## ANNEX 2.2

### FORM D

**Workshop Job Card**

<table>
<thead>
<tr>
<th>Equipment</th>
<th>Type</th>
<th>Make</th>
<th>Fleet No.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Speedo/Hours run</td>
<td>Time &amp; Date in</td>
<td>Time &amp; Date out</td>
<td></td>
</tr>
<tr>
<td>Type (tick) Preventive (P)</td>
<td>Corrective (C)</td>
<td>Breakdowns (B)</td>
<td></td>
</tr>
<tr>
<td>Accident (A)</td>
<td>Mod (M)</td>
<td>Warranty (W)</td>
<td>Reword</td>
</tr>
<tr>
<td>Priority (tick)</td>
<td>Top (1)</td>
<td>Urgent (2)</td>
<td>Normal (3)</td>
</tr>
</tbody>
</table>

**Work Required**

<table>
<thead>
<tr>
<th>Est. Cost</th>
<th>Authorized by</th>
<th>Date</th>
</tr>
</thead>
</table>

<table>
<thead>
<tr>
<th>Date</th>
<th>Workman</th>
<th>Work Done</th>
<th>Hours</th>
</tr>
</thead>
</table>

(Two thirds of reverse side printed like this for work done and labor hours.)

**Spares Used:**

<table>
<thead>
<tr>
<th>Date</th>
<th>Req'n No.</th>
<th>Item</th>
<th>Part no.</th>
<th>Bin No.</th>
<th>Quantity</th>
<th>Unit Cost</th>
<th>Total</th>
</tr>
</thead>
</table>

(One third of reverse side printed like this for spares used.)

Worked checked by

Cost of spares b/f o'leaf

Total hrs @ per hr =

Total cost of spares

Time in w'shops

Total cost of tires*

Posted to Job Card Summary by

Cost of labor

Total cost of job

* Tire costs to be shown separately from spares.
## ANNEX 2.2

FORM E

**Workshop Job Book or Register (sample page)**

<table>
<thead>
<tr>
<th>Date in</th>
<th>Job No.</th>
<th>Equipment Type</th>
<th>Fleet No.</th>
<th>Work Required</th>
<th>Priority Type</th>
<th>Date Out</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Brief Description</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>


ANNEX 6.1

TERMS OF REFERENCE
Preparation of Equipment
Management Improvement Plans

SCOPE OF WORK

1. The consultants are required to make a survey of the services required from the equipment department, the resources available to provide those services, the constraints affecting their efficient utilization, and the level of performance achieved by the department. They are then required to draw up a program or action plan for improving performance, with recommended changes phased over a suitable time scale to enable improvements to become permanent. Resource planning must cover a five-year period.

2. The subjects and functions to be assessed are:

   2.1 The equipment and its operation.
   2.2 The maintenance of the equipment.
   2.3 The supplies and spare parts function.
   2.4 The financial, administrative and accounting functions.
   2.5 The staff (workforce and management).

3. The following aspects for each of the above subjects or functions must be dealt with:

   3.1 Policy
   3.2 Organization
   3.3 Procedures
   3.4 Accountability/Audit
   3.5 Suitability (quality and quantity)
   3.6 Effectiveness/utilization
   3.7 Efficiency/cost
   3.8 Legal and safety aspects
   3.9 Resource: existing resources
   3.10 Requirements for next five years

4. Final Report. A comprehensive report assessing the existing situation and recommending appropriate changes in policies, procedures and resources is required. This will include delineation of future performance targets and requisite management information systems. Information required for the management information systems described in Eaton (1984) should be provided, to the extent available.

5. The following points must be included in making the survey, the assessment, recommendations, and plan. Where information requested is not available, this should be stated and comment made on the reason, e.g., system never implemented or system lapsed and why. Recommendations are required in all cases where a situation is not satisfactory.
6. **Equipment and its Operation.** (Use form given at Attachment (i).)

6.1 Carry out an equipment audit:

(a) Provide full list of power-operated equipment on strength with a replacement cost exceeding US$1,000.

(b) Classify by type, make, model, age and location.

(c) Assess the condition of each item of equipment and make recommendations for disposal or repair/rehabilitation. In general the terms good, fair, poor, and bad will be used to describe the general mechanical condition of each item of equipment and the condition of each of the major units or assemblies comprising the equipment. Good will indicate an average expectation of 24 months or more normal running without the need for a major repair or overhaul, fair will indicate an expectation of 6 to 24 months, and poor 1 to 6 months. Bad will indicate a need for immediate action, either repair or disposal.

<table>
<thead>
<tr>
<th>Conditions</th>
<th>(time remaining serviceable before major overhaul - months)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bad</td>
<td>Poor 6</td>
</tr>
<tr>
<td></td>
<td>Fair 24</td>
</tr>
<tr>
<td></td>
<td>Good</td>
</tr>
</tbody>
</table>

Assess remaining economic life of equipment and estimate approximate magnitude of repair costs till scrapping.

6.2 Evaluate present policy in respect of economic life and replacement of equipment.

6.3 Comment on present policy in respect of the standardization of the equipment fleet and make recommendations, including quantified economic justification where possible.

6.4 Assess standard of driving and operation of equipment. Quote accident rate by class of equipment in terms of the average hours worked or kilometers run per accident per annum. Assess operator and driver training requirements.

6.5 Quote average utilization for each class of equipment for the previous month, year-to-date and previous year, and recommend appropriate norms for the future taking into account prospective improvements in operator and mechanic training, spare parts supply and equipment renewal.

6.6 Assess suitability of operational information and records system (Eaton Vol. II, 1984).

6.7 Estimate demand for all major items of equipment over next five years assuming present and probable future efficiency.
6.8 In light of total estimated demands (6.7), the condition of the existing fleet (6.1), appropriate replacement policies (6.2, 6.3), and reasonably anticipated improvements in efficiency (6.4, 6.5), recommend procurement schedule in accordance with Attachment (ii) for fleet replacement and, if necessary, expansion.

7. Equipment Maintenance

7.1 Evaluate present maintenance policy, procedures, and the effectiveness of their application.

7.2 Assess the suitability and adequacy of mobile workshops, workshops buildings, lay-out, equipment and tools. Make sketches of any proposed improvements to lay-out or for extensions or new workshops and compile price list of any additional tools and equipment required.

7.3 State average availability of equipment by class for the month, year-to-date and for the previous year in hours.

7.4 Report on arrears of preventive and of corrective maintenance and repair work for each workshop. List unserviceable equipment. State how long each item has been unserviceable and the reason.

7.5 State ratio of productive to non-productive staff, average labor cost and labor rate(s) charged for maintenance.

7.6 State the average ratio of the cost of preventive to corrective maintenance by class of equipment.

7.7 State the average maintenance cost per kilometer or per hour for each class of equipment.

7.8 State the sulphur content of the fuel oil used for diesel engines, type of engine oil used and current oil change periods for the different classes of equipment. State whether spectrographic analysis systematically used for diagnosing preventive maintenance needs.

8. Supplies & Spare Parts Function.

8.1 State the total value of spare parts held in stock, the values for the main classes of equipment, the total value issued from the stores, that purchased and issued direct last year, and estimated value of redundant stock. State the date and value of the last write off or boarding of redundant spares.

8.2 State the service level (orders filled - total orders) achieved for spare parts from departmental stocks during the past 12 months, the number of 'emergency' orders and average delivery time for the latter.
8.3 Evaluate the present system of stock control, anticipation of requirements, re-order quantities and re-order levels.

(a) Make a sample stock check to verify records and security. State date and extent of last stock check, show details of the number of line items checked, level of discrepancies and by whom checked (i.e., staff from equipment branch or from other departments). Compare actual practice with policy regarding frequency and thoroughness of stocktaking.

(b) State the present stock-out position and give an indication of the consequent equipment downtime and its economic cost.

(c) Describe the position, grade and status of the person responsible for stocking and order levels.

8.4 Estimate the handling and overhead costs on spare parts issued and number of line items issued per month per store and per member of the stores staff.

8.5 Assess the suitability and adequacy of the stores buildings, binning and handling facilities.

8.6 Evaluate the present system of distribution of spares from central stores to the local workshops and mobile mechanics. State how long it normally takes from the time an order is first placed until it is in the hands of the mechanic at the machine.

8.7 Review the procurement, import licensing, freight forwarding and customs clearance policies and practices.

8.8 In light of anticipated fleet size and characteristics (6.8) and probable improvements in supplies management (8.3-8.7), recommend appropriate overall level of investment in spare parts and supplies.


9.1 Review budget requests, allocations and actual expenditures over last five years. State whether annual reports have been published during the last five years, and where available, provide extracts indicating the performance of the department and use of resources. Where a funding scheme is in operation a summary of the balance sheet and main accounts will be required over the last five years.

9.2 For the last full year and for the present year to date give a breakdown of expenditure by main accounts or function. Review the appropriateness and effectiveness of the budgetary control system. Clarify whether line managers are given functional budget control with appropriate latitude between budget items, particularly whether economies in one category are available for alternative uses.
9.3 Forecast financial requirements for the next five years on the basis of estimated equipment, spares, workshops and staff requirements.

9.4 Review the suitability and accuracy of the capital assets register and system of amortizing equipment capital costs.

9.5 State whether equipment amortization charges include interest on capital and an inflationary element for replacement of equipment and the extent to which reported total costs reflect the full economic cost of providing an equipment service including overheads. If total costs are not covered from the budget of the equipment using agencies, identify the government budget which covers the difference.

9.6 Compare the numbers and cost of the administrative and accounting staff with the value of the equipment and the numbers and cost of staff for the operating and maintenance branches.

9.7 Compare equipment costs at replacement prices including interest at market rates with the cost of hiring from the private sector.

9.8 Compare wages paid with those paid in the private sector.

9.9 Review compliance of the equipment branch, in respect of licensing, insurance, employment, safety and other regulations which apply.

9.10 Review the costing and management information system and recommend improvements therein (Eaton, 1984).

10. Staff

10.1 Carry out a staff audit for workforce and management staff. (Supervisory staff to be included in management category.) Show the establishment and numbers in post for each trade and grade.

10.2 Review the past five years with regard to annual turnover of staff, and numbers trained, promoted and recruited.

10.3 Assess the skills required, skills available and productivity of the staff.

10.4 Estimate staff requirements in the various grades over next five years, compare with present staff strength and draw up proposals for training, development and recruitment.

10.5 Review methods used and persistence of management staff in directing and motivating workforce and degree of success achieved, including review of the annual personnel performance report and staff appraisal and counselling system, the appropriateness of the work done by the various levels of management staff, the effort expended and amount of supervision given. Assess the attitude of management staff to management with regard
to knowing the situation and assessment of information (e.g., whether comparative and trend analysis of information is practised) and degree of self motivation.

10.6 Review briefly the disciplinary procedure and state number of staff, if any, given warning letters or dismissed for misconduct or incompetence during the last two years.

10.7 Make recommendations for improving motivation including the various types of incentives and changes in management methods which may be feasible.

10.8 Review existing job description and recommend improvements to include statements of key objectives, tasks and performance indicators for the various levels of management.