2.3 Spare Parts Cycle Management

Management of equipment is sustained by proper management of spare parts. It can be said that achievement of medical equipment management depends on whether the spare parts management (or spare parts control) can be properly done. Spare parts management requires a broad range of technology, experience and knowledge of medical equipment. In addition to this, it requires the ability to estimate necessary spare parts. If C/Ps are able to carry out spare parts management, technology transfer in the field of medical equipment management will be enhanced. Technology transfer in the area of spare parts management is, therefore, one of the most important tasks in MMS.

2.3.1 Classification of Spare Parts

Spare parts are essential for maintaining and repairing medical equipment. Accessories and consumable components that have been described so far are necessary for maintenance and inspection. Components including these accessories and consumable components that are used for maintenance and repair will generically be referred to as spare parts from now on. The spare parts are classified into various categories as shown in Figure 2.9 according to lifespan and purpose for use.

![Figure 2.9 Classification of spare parts according to the usage and life-span](image-url)

**Figure 2.9** Classification of spare parts according to the usage and life-span

Part Two: Basic Maintenance and Management of Medical Equipment
According to their purpose, spare parts are classified into one of two categories: that of maintenance and that of repair. The spare parts used for maintenance (maintenance parts) are classified into five groups according to the lifespan as shown in Figure 2.8. Spare parts used for repair (repair parts) are mainly used for random and wear-out failures, and are divided into two groups; those of long lifespan and those of semi-permanent lifespan. The maintenance parts are required to conform to particular specifications of the equipment. On the other hand, most semiconductor parts and electronic parts, which are used as repair parts, can be used on any equipment. However, advanced technique is often required in repair work that utilises semiconductor and electronic parts.

However, maintenance parts often belong to the category of spare parts for repair, because they deteriorate or breakdown. Conversely, repair parts are used for carrying out the preventive repair, i.e., faults found during inspection of equipment. Thus, use of the maintenance parts and repair parts often overlaps.

In general, costly PCBs are stocked even for general medical equipment because there is lack of advanced repair technique that utilises semiconductor and electronic parts. However, as failure occurrence on PCBs is rare, almost all PCBs that are stocked will possibly become “dead stock” before use. If costly PCBs are stocked without an explanation of when they will be needed, it is an extravagant expense of money (Note 2.17).

On the other hand, equipment worth tens of thousands of dollars might become irreparable due to unavailability of PCBs. Therefore, it is necessary to consider stocking PCBs rationally and economically. Larger stocks of electric and electronic parts are encouraged because they are not expensive, and can be used commonly for any equipment, e.g. capacitor set, diode set, fuse set, IC set, resistor set and transistor set.

### 2.3.2 Section Responsible for Spare Parts Management

One of the difficulties in spare parts management is to determine which section should manage it. For instance, spare parts management is sometimes left to individual wards after distribution. But this is not a rational strategy, because these spare parts will be locked away or not properly arranged unless the ward manager has high consideration for spare parts. As a result, the spare parts may not be effectively used.

In Islamabad Children's Hospital for example, staff in the store section took special training on logistics management and had no problems with their routine work. However, they did not know much about spare parts technically, making it difficult for them to prepare the spare parts requested by the ME section even if the spare parts were available. For this reason, the store section recommended that spare parts be managed under the ME section.

In NMCHC for example, spare parts including consumables are managed by the ME section under the direct control of Hospital Administrative Bureau (see also Photo 2.11). However, the Accounting Bureau prefers to manage spare parts while the Administrative Bureau preferred that the ME section manage them.

In the case of Bach Mai General Hospital, Vietnam for example, the ME section carries out all activities of equipment management from procurement to distribution of medical goods, instrument parts and spare parts, etc. In this hospital, handling specialised materials was established and left with the ME section.
Thus, responsibility for management of spare parts varies according to hospital management policy. It is rational that goods used in a specific section are managed under the specialised section for effective use. Therefore, it is encouraged that spare parts and consumables for medical equipment be managed by the ME section.

However, it is necessary to continue training personnel for establishing rational management of spare parts.

### 2.3.3 Carrying Out Spare Parts Cycle Management

Generally speaking, spare parts for medical equipment in developing countries are expensive and valuable assets. Therefore the spare parts are required to be managed economically and reasonably, and for this reason, carrying out spare parts cycle management is important. Such management completes one cycle in one year, which is similar to the medical equipment maintenance cycle. The basic flow of the spare parts management is shown in Figure 2.10.

Stocked and newly procured spare parts should be registered. Based on this, an inventory list, which shows the current balance of each spare part is made. Stock control is carried out to ensure inventory accuracy (this means the process covering the delivery, registration, use and stocktaking).

Stocktaking (or inventory check) is carried out to ensure accurate stock confirmation comparing between the numbers of use and inventory figures. Stock-shortage or newly required spare parts found during the stocktaking will be estimated for procurement, which is carried out according to the existing Government or Hospital Rules and Regulations. Acquired spare parts are stocked and added to registration and the inventory afresh.

A practical example of the spare parts cycle management being operated in NMCHC is illustrated in Figure 2.11.

Spare parts cycle management is divided into two components, i.e. stock control and procurement. These components are actually operated in connection with the internal procedure. In the stock control component, delivery, stock, registration and distribution are processed in turn. Records of information such as name, specifications and code numbers of spare parts and make of registration, and inventory list are very important systems to monitor the number and kind of individual spare parts. In addition, carrying out the inventory check that compares and confirms across the actual inventory and the record is necessary to do an accurate stock control.

In the procurement process, the store manager estimates necessary spare parts based on the result of the inventory except upon urgent request. This estimation is sent to the Administrative Bureau that manages the ME section in the form of a proposal which is checked, after which it is sent to the Drugs and Material Procurement Committee, where it is counter-checked.

The counter-checked proposal is sent to the Accounting Bureau and then to the hospital director for approval and later is returned to the drug and material procurement committee. This committee executes procedures of marketing research, inventory check, tender and contract, etc., and carries out the purchasing. The acquired spare parts are stocked before they are used, and the remaining spare parts are kept in storage. At this point, newly acquired parts are included on the inventory list. This list is balanced by comparing the parts entry/register and parts delivered to stations or wards.
The above-mentioned main procedures are explained as follows:

1) Registration and Inventory List

Each stocked and newly procured spare part is given a hospital code number. Information from the invoice or spare part specifications is relevant for creating or formulating the spare parts code number. This code is a key to managing hospital control of spare parts. On the other hand, the manufacturer's code number is essential to procure spare parts correctly.

The following information is necessary for spare parts registration:

- **Name of spare part**
- **Code number**: Original number of the hospital. Several types of numbers are used with the ID number of equipment, which uses the spare parts. The identification number that shows parts and items in this ID is added.
  
  Example from NMCHC:
  
  \[
  \text{G96-007-020} \rightarrow \text{G96-007-01} 
  \]
  
  Serial number of spare part that is put instead of equipment identification and serial number
  
  Same ID number as equipment

- **Manufacturer’s Code No.**: Number that equipment or spare parts manufacturer gives to equipment spare parts. It is necessary to indicate this number for easy procurement;

- **Specification**: e.g. type, size, weight, voltage, name, serial no. and application;

**Figure 2.11** Spare parts cycle management and internal management procedure flowchart (NMCHC, as of 2002)
- **Number of contents**: Plural quantities might be contained in one package. This may be included in item specification;
- **Name of manufacturer**: Name of manufacturer producing the spare parts. It does not necessarily conform to the equipment manufacturer;
- **Unit price**
- **Type of provision**: It is the same as the equipment. Refer to paragraph 2.2.1;
- **Name of equipment**: Name of equipment that requires spare parts;
- **Manufacturer**
- **Model No.**
- **Serial No.**: The specifications of parts are often different even if equipment is of same model. When ordering spare parts it is important to indicate the serial number of the equipment in order to procure correct spare parts.

Appendix-10 shows an example of the report being used in NMCHC that lists the movement of spare parts.

2) **Internal Delivery and Use**

Figure 2.12 shows an example of the utilisation procedures of spare parts that are being stocked in NMCHC. The procedures are complicated because of differences of opinion between the Accounting Bureau and the Administrative Bureau as to who should take responsibility for spare parts management. When spare parts are needed, the ME section fill in a ‘material request form’; this is a standard form similar to one used by other hospital wards and departments. This standard format is submitted to the Accounting Bureau. After this, the Accounting Bureau will issue a ‘material distribution form’. The requested spare parts are delivered after both request and distribution forms are endorsed by the Administrative Bureau and the hospital director.

When the spare parts are delivered, the person in charge of the store records the delivery in the pickup/delivery station form (BIN card) attached to each group of spare parts. An inventory check is carried out twice a year whose figures should match with the BIN card figures. If the figures match, the director of the Administrative Bureau signs the pickup/delivery form as proof that the stock control has been carried out correctly. Both spare request form and delivery form are attached to the technical service report.

![Figure 2.12 Procedures for use of stocked spare parts](NMCHC, as of 2002)
3) Stocktaking

It is necessary to take inventory of the spare parts at least twice a year, during the first half and the second half of the year to ensure accurate stock confirmation [Note 2.18]. NMCHC for example, has stock of 2,100 items of 250 different types of spare parts which were provided both under the grant aid of the Government of Japan and technical cooperation of JICA (as of 2002). A BIN card is put on each type of spare part. Records on the BIN card are compared with the existing spare parts stock, and the result is entered in the database.

However, when C/Ps working at the site carry out stocktaking, they may have problems knowing the name of a part, its purpose and understanding the meaning of stocktaking.

4) Estimation

All the consumable parts have individual lifespans as shown in Figure 2.9. The lifespan for each spare part can be determined through the manufacturer's instructions, experiences, etc. In addition, knowledge in the field of material engineering and safety engineering can be useful. On the other hand, the lifespan of spare parts is also influenced by the manner in which equipment is handled and environmental conditions. Therefore, estimation of necessary spare parts cannot be done automatically; it is necessary to consider other elements. Although the general principle of spare parts estimation described so far may not apply, a flowchart as shown in Figure 2.13 could be recommended. The following procedures are required to be followed when estimating necessary spare parts in large hospitals:

1. First of all, carry out the survey for utilisation of individual equipment and inventory check for spare parts,
2. The survey for the utilisation of the equipment should be done as described in paragraph 2.2.1,
3. Ensure that the survey report and equipment list are the same as above,
4. Evaluate the utilisation of individual equipment items: e.g. fully utilised, partly utilised, not utilised, malfunctioning, not working and not used (with some reasons),
5. Choose a medical equipment item concerned,
6. Based on the utilisation, make a list of necessary spare parts for the concerned equipment referring to the instruction manual, experience, knowledge of material engineering, and so on,
7. Determine the lifespan of the listed necessary spare parts. The reference matter is the same as step 6,
8. Carry out the inventory check,
9. Report the result of the inventory check,
10. Compare the two reports (steps 6 to 9), and determine the kind and amount of the spare parts,
11. Procedures (steps 6 to 10) apply to all medical equipment. This information is collated as a proposal for submission to the hospital authority.

5) Procurement

To procure necessary spare parts, the following should be taken into account: consumption report, selection of suppliers, contract conditions, payment, and stock up to distribution. The procurement committee plays a central role in these processes. In developing countries, spare parts procurement is, however, very difficult due to the following reasons:

- Most spare parts for medical equipment provided by grant aid cannot be procured in the local market;
- Even if suppliers who deal with spare parts exist, they are not interested in dealing with a variety of spare parts for a small amount of money;
- The unit price of many spare parts that can be bought in the local market is two or more times the regular price;
The spare parts of medical equipment become big financial loads on hospitals because of the large amount of money involved; Personnel who can estimate necessary spare parts and negotiate on procurement with suppliers lack training.

It is for these reasons that a lot of equipment provided through grant aid is confronted with shortage of spare parts. Therefore, many developing countries find it difficult to sustain the procurement of spare parts for donated equipment. On the other hand, if the kind and amount of necessary spare parts are uncertain, procurement is also impossible. Technology transfer on spare parts management in developing countries is demanded, based on the above reasoning, though the funding for this is another issue.
6) **Stock Control**

Capabilities to manage spare parts in many developing countries remain rather weak. This is not rational or economical. For instance, the spare parts are just heaped up on the floor or casually arranged on the shelf.

In the stock control, the person in charge of store should always monitor inventory figures. The famous ‘Saw-curve’ stock control is usually applied to manage the stock figures as shown in Figure 2.14. However, this can only be applied to spare parts with a short lifespan.

Inventory figures are determined first in this saw-curve. The stock figures depend on the lifespan and stock age of the spare parts, number of equipment, and budget. Planning for procurement is made before the repair parts are reduced to minimum stocks. The planning time depends on the time required to follow the procurement procedure of the hospital. The planning is adjusted according to time taken between ordering spare parts and receiving it.

Final stock figures should reduce to zero at the end of equipment lifespan in order to avoid unnecessary expenditure. To manage stock efficiently, an inventory check to confirm correct stock figures (stocktaking) should be carried out on a regular basis.

![Figure 2.14 Famous “Saw-curve” spare parts stock control](image-url)
2.4 Three Cycle Management

To achieve comprehensive MMS, life cycle, maintenance cycle and spare parts cycle management should integrally be carried out. The management system in which such different types of management are systematised into one is referred to as ‘Three Cycle Management’. The system of the three cycle management is shown in Figure 2.15.

The three cycles of management begin simultaneously. Life cycle management is carried out in a continuous process from acquisition, use, installation and maintenance/monitoring to decommissioning of equipment. Proceeding from life cycle management is maintenance cycle management, which is incorporated with the maintenance and monitoring stage of the life cycle management.

Spare parts cycle management is incorporated with the inspection and preventive repair stage in the maintenance cycle. Spare parts cycle management starts from registration of stocked spare parts, and continues with the processes of delivery, procurement, input, registration and stock. Through monitoring done during inspection and preventive repair, spare parts which are out of stock and newly required ones are estimated.

The movement of three cycle management is monitored by both series management and field management. The MEMC assumes responsibility for monitoring the movement of the entire three cycle management

Note 2.19). The ME section assumes responsibility for monitoring field management, which includes utilisation, performance and safety of medical equipment as well as spare parts consumption.

![Diagram](image-url)

**Figure 2.15** MMS by integrating the three cycle management: Though this system is applicable at both central and hospital levels, it is realistically necessary to run it in collaboration between both levels.
In developing countries where a systematic management system is not developed well, the introduction of the above-mentioned management system is essential. Experience shows that many developing countries face the following problems:

- Unutilised equipment
- Stockpiling of equipment in anticipation of a donor's withdrawal
- Lack of consumables and spare parts
- Inadequate plan for maintenance and management

One of the fundamental problems is that MMS is not well developed as yet, even though the repair system exists. The repair system does not monitor the status to maintain all the equipment allocated to the hospital, leaving the above-mentioned problems to prevail.

From the above lessons and experiences, we should consider the MMS economically, rationally and numerically. As a result of this consideration, the three cycle management methodology was developed by integrating the three cycles. However, although introduction of this system may be applicable to donor-supported health facilities, it is difficult to apply in hospitals and health facilities that are not donor-supported. Donor-supported health facilities may also have difficulties sustaining the system after donor support is withdrawn.

It is, therefore, advisable that the hospital should introduce this system in collaboration with the central workshop or specialised unit of medical equipment management of MoH where it exists. On the other hand, even in a country where a central workshop exists under MoH the integration of three cycle management is still a problem. However, all the concerned stakeholders should take part in the implementation of three cycle management appropriately.

Figure 2.15 shows the system composed of four specialised components as follows:

1) **Life cycle management**: Where it has been introduced, each individual hospital takes charge in principle. It is, however, required to be established at both the national and hospital levels.

2) **Maintenance cycle management**: ME section in the hospital or Central Workshop and Regional Workshop under MoH takes charge,

3) **Spare parts cycle management**: The central supply or procurement & logistics department under MoH takes charge,

4) **Entire monitoring**: The MEMC takes charge of this. This committee is required to be established at both the national and hospital levels.

At the national level, MoH needs to develop a system that will keep track of information related to the highly sophisticated or expensive medical equipment available in the hospitals or health facilities in the country.

It is emphasised that co-ordination/co-operation between the technical section that takes responsibility for maintenance and the logistics section (Note 2.20) that takes responsibility for material management including spare parts management is essential to sustain three cycle management. Although centralisation is required at the initial stage, decentralisation will be required in the future.

It must be remembered that the establishment and activities of the ‘Central Workshop’ are temporary measures as a means of self-defense in developing countries where the technical service environment in the private sector has yet to grow. With the development of society and economy in the future, therefore, the Central Workshop should be developed into a ‘Medical Equipment Administrative Body’ (Note 2.21) so that maintenance and repairs are transferred to the private sector. The ultimate goal is to recognise this section as a centre of medical equipment management in the country in co-operation with various academic organisations, other ministries and the private sector (Note 2.22).
2.5 Prediction of Maintenance Cost

In the case of in-house service, the spare parts cost takes most of the maintenance cost for sustainable operation of medical equipment. Maintenance costs required during the life of equipment are quite different depending on the equipment type; however, each cost can be predicted based on Figures 2.8 and 2.9. In addition, the necessary cost of all equipment with the passing of time from installation and use until decommissioning can be predicted. Variation of the maintenance cost with the passing of time has a certain pattern. On the other hand, existence or non-existence of an in-house service system brings a big difference in the management cost of equipment.

2.5.1 Maintenance Cost for Individual Equipment

Calculations are based on the example given of an anaesthesia apparatus, with the assumption that this equipment will be in use for ten years. Necessary consumables for this equipment are illustrated in Figure 2.16. The necessary costs shown in Table 2.4 can be obtained from this Figure. In this example, deterioration and breakdown of other parts (e.g. valves and tubes) and calibration cost for vaporisers are not included. The price for the actual equipment is about US$12,000; the maintenance cost for 10 years is US$8,000 which is 62% of the total equipment cost. This sounds expensive and thus it may be believed that it is cheaper to replace the entire apparatus. Therefore, when the equipment breaks down new equipment is often requested instead of considering the maintenance cost of existing equipment. This is obviously not rational and not economical. Remember that equipment breakdown is mostly caused by deterioration of consumable parts.

Where there is neither maintenance nor repair system, and absence of periodical inspection, operation of this equipment is about three years due to the deterioration of the breathing hose and

<table>
<thead>
<tr>
<th>No.</th>
<th>Item</th>
<th>Rep. Cycle</th>
<th>Price (US$)</th>
</tr>
</thead>
<tbody>
<tr>
<td>①</td>
<td>Co₂ absorber</td>
<td>Consumed daily</td>
<td></td>
</tr>
<tr>
<td>②</td>
<td>Mask</td>
<td>3 months</td>
<td>50</td>
</tr>
<tr>
<td>③</td>
<td>Breathing bag</td>
<td>6 months</td>
<td>50</td>
</tr>
<tr>
<td>④</td>
<td>Breathing hose</td>
<td>1 year</td>
<td>140</td>
</tr>
<tr>
<td>⑤</td>
<td>Oxygen sensor</td>
<td>2 years</td>
<td>400</td>
</tr>
<tr>
<td>⑥</td>
<td>Vaporiser</td>
<td>5 years</td>
<td>1,600</td>
</tr>
</tbody>
</table>

* Dependent on the safety standard, number of operations, and clinical policy of individual hospital.

Figure 2.16 Main accessories and consumable parts for an anaesthesia apparatus which requires regular replacement
Table 2.4 Ten year maintenance cost estimation for an anaesthesia apparatus

<table>
<thead>
<tr>
<th>No.</th>
<th>Item*</th>
<th>Replacement Cycle *</th>
<th>Unit Price (US$)</th>
<th>Replacement Time/10 years</th>
<th>Replacement Cost (US$)</th>
</tr>
</thead>
<tbody>
<tr>
<td>②</td>
<td>Mask</td>
<td>3 months</td>
<td>50</td>
<td>40</td>
<td>2,000</td>
</tr>
<tr>
<td>③</td>
<td>Breathing bag</td>
<td>6 months</td>
<td>50</td>
<td>20</td>
<td>1,000</td>
</tr>
<tr>
<td>④</td>
<td>Breathing hose</td>
<td>1 year</td>
<td>140</td>
<td>10</td>
<td>1,400</td>
</tr>
<tr>
<td>⑤</td>
<td>Oxygen sensor</td>
<td>2 years</td>
<td>400</td>
<td>5</td>
<td>2,000</td>
</tr>
<tr>
<td>⑥</td>
<td>Vaporiser</td>
<td>5 years</td>
<td>1600</td>
<td>1</td>
<td>1,600</td>
</tr>
<tr>
<td></td>
<td>Total</td>
<td></td>
<td></td>
<td></td>
<td>US 8,000</td>
</tr>
</tbody>
</table>

Note: Performing the regular inspection is prerequisite.

The equipment requires high maintenance cost. The cost in Table 2.4 seems to be a lot of money. However, it is considerably smaller than the cost in the absence of a maintenance system. The differences in infection risk and reliability are more difficult to quantify in this fashion, but would be of even greater concern (particularly to a patient). In addition, by carrying out maintenance and inspection, continuous operation and management of the equipment will result. By this effect, the equipment need not be newly bought for at least ten years.

2.5.2 Maintenance Cost all Entire Equipment, and Two Cost Peaks

The example of the anaesthesia apparatus described in paragraph 2.5.1 is applied to other types of medical equipment. Inspection is carried out on respective individual equipment, and the entire maintenance cost is predicted based on this so that the equipment group can be continuously maintained and managed as a whole. As a result, a high utilisation rate for the entire group of medical equipment is attained. For this reason, there is mutual correlation between maintenance cost and equipment utilisation rate.

If the lifespan of a medical equipment group that was provided in the same batch is set for ten years, the maintenance cost from installation to decommissioning for every half year can be predicted as illustrated in Figure 2.17. The ordinary cost is a cost that is constant as consumable components such as filters and surgical lamps are continuously replaced. Since the cost of parts involved in the middle and long lifespan as well as repair cost is included on the current cost, the pattern formed is predictable as shown in Figure 2.17.

The common pattern of maintenance costs is made up of two peaks. The first peak will appear around three years after installing the equipment. This is as a result of replacing spare parts and consumables that have a lifespan of two to three years. The second peak will appear about two to three years from the first peak (six to seven years after the installation). The cost of the second peak is predicted to be twice or more than the first peak, because both spare parts of two to three years lifespan and those of five to seven years lifespan are overlapped. ‘Prediction of the first and second peak’ was carried out in NMCHC in 1998, and this prediction compared very well with the ‘actual maintenance cost of the first peak’.
Figure 2.17  Two predictable cost peaks of the medical equipment group provided in the same batch, setting the life-span of 10 years

Figure 2.18 shows the relationship between the maintenance costs and the EURs with variation of time during five years. This covers a group of 90 items of medical equipment that were installed in April, 1997. The first peak appeared between the second half of 1999 (SH’99) and the first half of 2000.
almost three years after the equipment operation started. This actual peak compared very well with the prediction that was carried out in 1998. The cost begins to rise again in the second half of 2002, and is connected with the second peak prediction, which is in 2003 or 2004.

The average of the EURs during five years was 92% on cost basis and 94% on quantity basis, and US$ 39,346.00 in total was spent to maintain these high utilisation rates until SH’02 (see Table 2.5). Among these, costs that were spent for repairs on contracted-out services were US$ 213.00 as technical service fee and US$ 837.00 as transportation fee. The proportion of the repair cost by contracted-out service accounts for only 2.7% of the total maintenance cost. Therefore, even if this cost is added to the cost of repair by in-house, the entire cost for repairs is a small amount of expenditure. This is the grounds that "real breakdown" accounts for only 5.0-6.0% of all the equipment failures as mentioned in Part 1.

In other words, breakdown of equipment hardly occurs if inspection and monitoring are carried out on individual equipment items following the MMS. This shows how large the difference in cost is between the repair system and the maintenance system as mentioned in paragraph 2.5.1. It is obvious that even here the MMS by repair system lacks relevance.

Table 2.5  Maintenance and repair cost flow for the equipment group installed in 1997—NMCHC (Total number of equipment = 90, Total price of equipment = US$ 793,959.00)

<table>
<thead>
<tr>
<th></th>
<th>FH98</th>
<th>SH98</th>
<th>FH99</th>
<th>SH99</th>
<th>FH00</th>
<th>SH00</th>
<th>FH01</th>
<th>SH01</th>
<th>FH02</th>
<th>SH02</th>
<th>Subtotal</th>
</tr>
</thead>
<tbody>
<tr>
<td>Spare parts GA</td>
<td>67</td>
<td>2,161</td>
<td>1,266</td>
<td>6,558</td>
<td>3,376</td>
<td>1,450</td>
<td>916</td>
<td>1,407</td>
<td>1,709</td>
<td>1,201</td>
<td>20,131</td>
</tr>
<tr>
<td>Spare parts TC</td>
<td>707</td>
<td>10</td>
<td>358</td>
<td>1,988</td>
<td>5,067</td>
<td>1,668</td>
<td>1,012</td>
<td>1,686</td>
<td>213</td>
<td>5,456</td>
<td>18,165</td>
</tr>
<tr>
<td>Labour cost</td>
<td>0</td>
<td>0</td>
<td>47</td>
<td>153</td>
<td>0</td>
<td>13</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>213</td>
</tr>
<tr>
<td>Transportation</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>637</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>637</td>
<td>837</td>
</tr>
<tr>
<td><strong>Subtotal</strong></td>
<td>774</td>
<td>2,171</td>
<td>1,644</td>
<td>8,593</td>
<td>9,233</td>
<td>3,131</td>
<td>1,928</td>
<td>3,293</td>
<td>1,922</td>
<td>6,657</td>
<td>US$29,450</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th></th>
<th>FH98</th>
<th>SH98</th>
<th>FH99</th>
<th>SH99</th>
<th>FH00</th>
<th>SH00</th>
<th>FH01</th>
<th>SH01</th>
<th>FH02</th>
<th>SH02</th>
<th>Subtotal</th>
</tr>
</thead>
<tbody>
<tr>
<td>Spare parts GA</td>
<td>67</td>
<td>2,161</td>
<td>1,266</td>
<td>6,558</td>
<td>3,376</td>
<td>1,450</td>
<td>916</td>
<td>1,407</td>
<td>1,709</td>
<td>1,201</td>
<td>20,131</td>
</tr>
<tr>
<td>Spare parts TC</td>
<td>707</td>
<td>10</td>
<td>358</td>
<td>1,988</td>
<td>5,067</td>
<td>1,668</td>
<td>1,012</td>
<td>1,686</td>
<td>213</td>
<td>5,456</td>
<td>18,165</td>
</tr>
<tr>
<td>Labour cost</td>
<td>0</td>
<td>0</td>
<td>47</td>
<td>153</td>
<td>0</td>
<td>13</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>213</td>
</tr>
<tr>
<td>Transportation</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>637</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>637</td>
<td>837</td>
</tr>
<tr>
<td><strong>Subtotal</strong></td>
<td>774</td>
<td>2,171</td>
<td>1,644</td>
<td>8,593</td>
<td>9,233</td>
<td>3,131</td>
<td>1,928</td>
<td>3,293</td>
<td>1,922</td>
<td>6,657</td>
<td>US$29,450</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th></th>
<th>FH98</th>
<th>SH98</th>
<th>FH99</th>
<th>SH99</th>
<th>FH00</th>
<th>SH00</th>
<th>FH01</th>
<th>SH01</th>
<th>FH02</th>
<th>SH02</th>
<th>Subtotal</th>
</tr>
</thead>
<tbody>
<tr>
<td>Spare parts GA</td>
<td>67</td>
<td>2,161</td>
<td>1,266</td>
<td>6,558</td>
<td>3,376</td>
<td>1,450</td>
<td>916</td>
<td>1,407</td>
<td>1,709</td>
<td>1,201</td>
<td>20,131</td>
</tr>
<tr>
<td>Spare parts TC</td>
<td>707</td>
<td>10</td>
<td>358</td>
<td>1,988</td>
<td>5,067</td>
<td>1,668</td>
<td>1,012</td>
<td>1,686</td>
<td>213</td>
<td>5,456</td>
<td>18,165</td>
</tr>
<tr>
<td>Labour cost</td>
<td>0</td>
<td>0</td>
<td>47</td>
<td>153</td>
<td>0</td>
<td>13</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>213</td>
</tr>
<tr>
<td>Transportation</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>637</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>637</td>
<td>837</td>
</tr>
<tr>
<td><strong>Subtotal</strong></td>
<td>774</td>
<td>2,171</td>
<td>1,644</td>
<td>8,593</td>
<td>9,233</td>
<td>3,131</td>
<td>1,928</td>
<td>3,293</td>
<td>1,922</td>
<td>6,657</td>
<td>US$29,450</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th></th>
<th>FH98</th>
<th>SH98</th>
<th>FH99</th>
<th>SH99</th>
<th>FH00</th>
<th>SH00</th>
<th>FH01</th>
<th>SH01</th>
<th>FH02</th>
<th>SH02</th>
<th>Subtotal</th>
</tr>
</thead>
<tbody>
<tr>
<td>Spare parts GA</td>
<td>67</td>
<td>2,161</td>
<td>1,266</td>
<td>6,558</td>
<td>3,376</td>
<td>1,450</td>
<td>916</td>
<td>1,407</td>
<td>1,709</td>
<td>1,201</td>
<td>20,131</td>
</tr>
<tr>
<td>Spare parts TC</td>
<td>707</td>
<td>10</td>
<td>358</td>
<td>1,988</td>
<td>5,067</td>
<td>1,668</td>
<td>1,012</td>
<td>1,686</td>
<td>213</td>
<td>5,456</td>
<td>18,165</td>
</tr>
<tr>
<td>Labour cost</td>
<td>0</td>
<td>0</td>
<td>47</td>
<td>153</td>
<td>0</td>
<td>13</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>213</td>
</tr>
<tr>
<td>Transportation</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>637</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>637</td>
<td>837</td>
</tr>
<tr>
<td><strong>Subtotal</strong></td>
<td>774</td>
<td>2,171</td>
<td>1,644</td>
<td>8,593</td>
<td>9,233</td>
<td>3,131</td>
<td>1,928</td>
<td>3,293</td>
<td>1,922</td>
<td>6,657</td>
<td>US$29,450</td>
</tr>
</tbody>
</table>

G. Total: US$ 39,346

Part Two: Basic Maintenance and Management of Medical Equipment
2.6 Database Management

The database is useful for the efficient performance of three cycle management. The following five data files are important in the MMS:

1) **Actual equipment**: Main (or master) file in which the data of medical equipment as mentioned in section 2.1 is entered and displayed. It manages the equipment registration, equipment list and utilisation rates.

2) **Optional equipment**: File that registers and displays the data of equipment which is attached to the actual equipment. Equipment registration, equipment list, utilisation rates are managed.

3) **Spare parts**: File that registers and displays the data of spare parts shown in paragraph 2.3.3. Results of inventory check, in/out for stock, and stocked spare parts are managed.

4) **Service record and history**: File that records the service reports of inspection, installation, repair, etc. It manages the service report, service cost and service history of individual equipment.

5) **Equipment manufacturers/Local agencies**: Manages the address, contact person, responsible person for technical matters, etc. to provide solutions and feedback, and to access information, etc.

A basic design of database (data entry) in which the above-mentioned files are integrated according to the life cycle of equipment is illustrated in Figure 2.19. Data entry or data reference at each stage on the life cycle of equipment is carried out as follows:

- **Installation/commissioning**: Data of both optional equipment and actual equipment on registration or commissioning are entered into optional equipment and master files respectively. Based on this, the equipment inventory list is made;

- **Use of equipment**: Training on operation and maintenance are often conducted by the manufacturer or local agency. In addition, consumables for use on equipment are procured from them. Moreover, AMC is concluded with them. These data are entered into the manufacturer/local agency file.

![Figure 2.19](image-url)
• **Monitoring/Maintenance:** Data resulting from inspection and preventive repair is recorded. The data is sometimes referred for next repair or maintenance. Particularly, in the service history of equipment it is very important to know operating conditions, service qualities, necessary spare parts, maintenance policies, technical training, etc. These data are entered into the service record/history file. On the other hand, spare parts used during inspection and preventive repair are entered into the spare parts file. In addition, necessary spare parts are procured from manufacturers or local agencies. These data need to be entered into the manufacturer/local agency file and spare parts file respectively.

• **Decommissioning:** When equipment becomes old or unserviceable, data on the service record/history file is referred to for decommissioning. Appendix-11 shows an example of outline of the database being used in NMCHC that integrates the above-mentioned five files as a relational database. In fact, this database mostly covers the range of inventory management of medical equipment including related records and documentations. Appendix-11 is a comprehensive internal inventory management of equipment in the hospital. If this is applied at a central level under MoH, an integrated and multidisciplinary approach that takes into consideration the administrative, clinical, financial, technical, logistical and organisational aspects is carried out. This concept is applicable at both the national and hospital levels (see Figure 2.20).

![Diagram of database operation](image-url)

*Figure 2.20* A concept to operate the database
2.7 Management Tools

Records and reports taken from three cycle management are very important references to monitor the utilisation of equipment and safety/reliability, and to set up the maintenance and management plan. In fact, the records and reports are used as management tools of medical equipment management. Records and reports provide adequate information which is necessary for presentation to stakeholders.

The main management tools are as follows:

- **Test certificate issued by equipment manufacturers**
  Reputable manufacturers always attach the results of examinations carried out on equipment before shipment. Refer to the data recorded in this for the inspection;

- **Medical equipment registration form (Appendix-6)**
  This is similar to the patient clinical record in the clinical sector. Therefore, this is a most basic document where all necessary information on an individual item of equipment is recorded;

Figure 2.21 shows two methods of filing and utilising this document. Each method has merits and demerits respectively as follows:

![Two methods for filing the equipment registration form](image_url)
(1) Filing according to the ward and department:
   Merit: It is easy to file and to find individual equipment. In addition, the amount of the material for filing is small.
   Demerit: The document is not active.
(2) Filing by equipment type:
   Merit: Because service information is added to the equipment, all information in the passage of the time of the concerned medical equipment can be monitored.
   Demerit: The amount of the filing materials is too large.

- **Equipment inventory list** (Appendix-7)
  Survey the utilisation of individual equipment every six months, and submit the result and up-date to the hospital;
- **Service report** (Appendix-4)
  Record all services such as inspection, repair, installation, etc. regarding concerned medical equipment. This report is used as a reference for failure analysis, statistics of service costs and failure solution;
- **Service history** (Appendix-8)
  Record the service history of individual equipment starting from installation, and continuing to maintenance, repair and adjustment in passage of time. This is the history of the equipment throughout its lifespan. Carry out appropriate measures referring to the service history when the next check time of the equipment is set;
- **Spare parts consumption report** (see Appendix-10: Spare parts inventory)
  Analyse the consumed spare parts, amount and frequency, and report to the hospital.
- **Medical equipment adjustment record**
  Record the fault symptom, method of calibration, measured results, etc. during inspection and preventive repair, and attach this to the service report. This record is used as a numeric reference for subsequent maintenance and repair;
- **Regular report**
  Report on the condition and utilisation of equipment. For instance, every three months for expensive equipment, and every six months for general equipment.
2.8 Evaluation Tools

When the existing ME section in a health facility is evaluated, the evaluation consultant usually asks "How many repair cases of faulty medical equipment by local engineers or technicians were completed" as an inquiry. However, inquiry based on opinion is not suitable due to the following reasons:

- Medical equipment must not break down while being used;
- Repair is not a basis for the medical equipment management, but maintenance and inspection are given top priority;
- By carrying out maintenance and inspection, the number of equipment failures will not continuously increase with the passing of time, and it conversely decreases and remains low in value (see Figure 2.22). This means that the "statistical graph on number of repairs" expressed in Figure 2.23 would not be used as an evaluation tool.

An example of the evaluation in three cycle management of the medical equipment is shown in Appendix-12. The tools to evaluate this are as follows:

1) EURs
   They monitor the utilisation rates on cost basis and quantity basis in individual wards and for the whole hospital. This is the overall and numeric evaluation of the MMS.

2) Maintenance/Repair cost
   It monitors necessary expenditures to maintain a high EUR.

![Graph for number of repairs and equipment utilization rates in NMCHC during five years (1998-2002): By implementing the maintenance system, the number of repairs decreased and remains low while the equipment utilization has remained high in value.](image-url)
Figure 2.23  Statistics on number of repairs as an evaluation tool in a hospital: This hospital has been maintaining equipment mainly by repair system, but not by maintenance system. All failures of the equipment are being considered to be a breakdown that needs repair as pointed out in Note 1.5. In addition, the number of breakdowns increased in the range of 15 to 60% every year as shown in this graph. According to the rate of this increase, the number of repairs after five years is predicted to exceed 500 in 2006. Can existing technical staff deal with such a large number of repairs? Moreover, does the hospital authority really evaluate the ME section carrying out such a large number of repairs?

3) **Annual report**
   It monitors the activity, result, statistics, analysis, progress, etc. as a summary of one year of activity.

4) **Mid/Long term maintenance management plan**
   It monitors necessary budget in economic and rational methodologies by carrying out the prediction of mid/long term necessary spare parts and of medical equipment lifespan.

5) **New equipment purchase plan**
   An economical and reasonable purchase plan can be understood.
Note 2.1  **Importance of co-operation with medical doctors in the field of medical equipment maintenance and management**—In many developing countries, doctors are interested in and support the purchase and deployment of more advanced equipment. On the other hand, there is not much concern for maintenance to achieve reliability; instead, the focus is on equipment usage. As a result, equipment breaks down frequently, prompting the doctors to seek remedial measures. When they fail to find these, equipment which is still in good condition (as good as new) is abandoned, and instead they wait for another donation or new purchase.

On the other hand, medical equipment is assessed from electronic and mechanical aspects, and equipment function is judged from the "functioning" or "non-functioning" viewpoint. The aspects of reliability and safety are not considered. Managers at both MoH and hospital levels also make assessments in the same vein. This means that recognition and evaluation of the ME section are viewed at the same level as a mere repair workshop similar to those found in town.

To correct this situation, the ME section or central workshop, by co-operating with donors, has developed a repair and technical guidance. Based on this, a proposal on recommendations for the improvement of MMS has been submitted to hospital management from the expert's position. Such a proposal is, however, written from an aspect-based situation on the site, and may not help to contribute to further development of management and administration of medical equipment technology at both hospital and national levels. This is one point that should be taken into consideration.

Guidance on maintenance and repair based on the situation at the site is essential, but it is not critical. The objective of technical co-operation is to disseminate and sensitise management to recognise that the ME section is not just a labour group on the site, but should also be considered and elevated to the level of hospital management. On the other hand, the future framework of the national administration system can be developed and guided on this activity. To do this, it is necessary to find medical doctors who are involved in management of medical equipment. This is one of the human resource development strategies. These doctors play the following roles:

- To have interest in medical equipment technology;
- To work in co-operation with ME section;
- To assess medical equipment management;
- To supervise the safety and management of medical equipment at the site;
- To be resource persons at seminars and workshops.

In addition to these, future co-operation with these doctors is essential to establish and implement the following systems:

- Implementation of Clinical Engineering;
- Implementation of the qualification and licence of medical equipment maintenance and management;
- Being part of developing medical engineering and technology;
- Development of education in the field of medical equipment technology;
- Establishment of academic society on medical equipment application and technology;
- Establishment of administration and supervision system for MMS in MoH.

Note 2.2  **In the absence of an ME section**, carrying out the maintenance cycle depends on a contracted-out service. However, there are problems in maintenance frequency carried out by an external organisation in developing countries as follows:
Suppliers or local agencies do not have a list of equipment of the user's facilities. Even if it is available, the service history is not recorded and managed; The designated inspection work is not carried out, and only rough visual inspections are carried out; Even if a small fault is found during inspection, preventive repair is overlooked, resulting in a real breakdown of equipment; Monitoring of the use of equipment is not done due to lack of interest; In the absence of monitoring it is not possible to collect data for future estimates and plans.

Note 2.3 In the hospital division of SGPGIMS for example, the existing Biomedical Engineering Department (BMED) is supposed to be part of the selection and procurement process in accordance with the Office Order, but it is not accepted. One of the reasons is that within BMED there is a persistent reliance on repair work for faulty equipment rather than on medical equipment life cycle management. Therefore, a technical evaluation from the management representative in the section is not obtained easily. In such a situation, the hospital authority made the decision to maintain this BMED composed of 12 engineers as a mere "Repair Centre". On the other hand, to achieve the technical evaluation required and to establish reliable medical equipment maintenance and management, the hospital authority established a new Clinical Engineering Section (as of 1997).

Note 2.4 In Southeast Asia, South Asia and Africa, products made in countries such as China, India, Korea, Pakistan and Taiwan have become more common. The range of manufactured equipment covers most models used in the clinical area. Various equipment produced in these countries is put in use together with equipment produced from European countries, USA and Japan as follows:

- Simple equipment: Laboratory incubators, Suction units, etc.;
- General equipment: Anaesthesia apparatus, Blood bank refrigerators, Centrifuges, Doppler fetus detectors, ECG equipment, Electro-surgical units, Infant incubators/warmers, Oxygen concentrators, Spectrophotometers, Sterilisers, etc.;
- Sophisticated equipment: Ultrasonic diagnostic equipment, X-ray equipment, etc.

These prices range from 1/3 to 1/5 of the price in European countries, Japan and the USA.

Manufacturers of such late-entry countries, the transfer of installation techniques, and the after-sales service to local representatives are often insufficient. Therefore, problems with the installation of newly purchased equipment and its continuous use often occur. In the absence of donor support, the hospital or MoH acquire such low-priced equipment arising from low bid price in normal tender.

In this case, the ME section alone must perform the installation for the reasons previously described. Because such equipment was acquired, the ME section should carry out a correct installation procedure, do an acceptance test, and give training on use of the equipment.

Note 2.5 Issues regarding NGO-donated equipment—The existence of NGOs in developing countries has led to a large amount of equipment being donated through some of their activities. However, the following issues should be noted regarding medical equipment donation:

- Much of the equipment is second-hand; therefore, these cannot be operated for a long time due to the unavailability of a sustainable supply of accessories and consumables, as well as an originally short lifespan. In addition, accessories and consumables have already deteriorated, or these are not included (see photo below). Furthermore, occasionally no operating manual is included;
- The equipment cannot be used for a long time since the maintenance and technical personnel development are not considered;
• Though looking new at first sight, equipment that could not have passed its performance and safety examination from the manufacturer is often brought in through the broker;
• Since donated equipment is directly brought in by NGOs, the Ministry of Health as supervisor to the recipient cannot monitor this, and also cannot take measures to improve the utilisation rates of equipment;
• There is a notion that the developing countries are dump sites for medical equipment. On the other hand, those who receive it cannot reject the equipment that NGOs bring in;
• Also, there exist some NGOs whose activities are pronounced depending on amount of medical equipment donated. Even in such cases, the above-mentioned problems are not taken into consideration.

Although facing shortages of budget and equipment, most NGOs are consistent and progressively achieve results with good technical co-operation from recipients. On the other hand, the Ministry of Health finds it difficult to control the above-mentioned examples. From the standpoint of the recipient, the Ministry of Public Health in Laos, for instance, is trying to make criteria for receiving medical equipment from NGOs (as of 2004).

A fetal actocardiograph donated by an NGO: The donor said that this equipment is new and has an optional function which can monitor inside the vagina. But actually this equipment was used once and had no such function (an optional accessory is required). Furthermore, the following problems restricted operating the equipment:
1) For use on 110V while outlet voltage is 220V in the country concerned,
2) Part of a transducer was broken,
3) Several accessories were not attached,
4) Difficult to procure consumables.

Note 2.6 Even if medical equipment is not maintained and inspected, the equipment can be used without failure for two to three years. However, if the operation is continued, then irreparable breakdown occurs. In a similar example, even if the car is not given the maintenance and inspection such as water, battery, oil, filter and tyre pressure (which are the user's responsibility), it can be driven for one or two years. But everyone who has experience driving a car can easily understand that if the car is continuously driven without maintenance and inspection, the car becomes faulty. If this fault is due to engine damage, it becomes irreparable. Moreover, maintenance of the car is directly connected with safety in driving.

Note 2.7 Facility Maintenance Section—To operate medical equipment smoothly, hospital facilities are required to be operated and maintained continuously in good condition. Various hospital facilities directly or indirectly affect operation of medical equipment:
• Air-conditioning system
• Central medical gas supply system
• Emergency generator
• Main power supply system
• Ventilation system
• Water supply system
• Water treatment system

To maintain the above-mentioned facility systems, NMCHC had set up the facility maintenance section. Staff from the facility maintenance section carries out daily inspection and its records to maintain good condition of the facility system. Both the ME
section and the facility maintenance section sometimes co-operate to ensure quality hospital service including medical equipment can run smoothly. Thus, the ME section should be directly and indirectly involved in maintaining the hospital facilities.

Note 2.8 Suitable personnel for ME section—Medical equipment technology consists of both medical science and engineering science. In developing countries, due to lack of better understanding, personnel interested in electric/electronics are appointed to work under medical equipment field. Therefore, their interest concentrates on repair of electric/electronic circuits, and they tend to disregard the safety, reliability and management of equipment.

However, the random failure that affects breakdown of electric/electronics is rare, and requires advanced technique for the repair. In other words, even if the personnel whose interest is only in electric/electronics received training for ten years, the technical advancement will not be able to reach the standard level of medical equipment technology.

Knowledge and experience of electric/electronics are very important and should not be underrated when dealing with management of equipment. The problem is how to acquire knowledge in medical science, physics, chemistry and biology combined with electrical/electronic engineering and other related engineering disciplines in order to improve medical equipment technology. In this case, technical background of the engineers and technicians is not so important.

From the above-mentioned viewpoints, in Cambodia where it is quite difficult to recruit medical equipment engineers and technicians, the concept of using appropriate personnel in the field of medical equipment services has been put in place as follows:

- About 60% of failure cases called breakdown are caused by deterioration of accessories and consumable components; these are, therefore, not real breakdowns. Wear-out failure is also included in this category. Moreover, there are a lot of failures that are caused by inappropriate handling and environmental conditions; these account for about 20%.

  It is not necessary to apply high technique for replacement of accessories and consumable parts. In addition, inappropriate handling and environmental conditions can be avoided through operators’ training and improvement of the installation environment. It can, therefore, be said that 80% of all breakdown cases can be prevented;

- The role of the MMS is to perform the three cycle management which is composed of ‘life cycle management’, ‘maintenance cycle management’ and ‘spare parts cycle management’, which exclude repairs to rectify breakdowns;

- Therefore, appropriate personnel are as follows:

  1) Personnel responsible for medical equipment management: The director of the hospital being the highest manager is the overseer of medical equipment management. Doctors in either the surgical section or the radiology section are suitable administrative personnel to supervise and monitor the MMS. This is a responsibility in addition to their clinical services, due to shortage of human resources. On the other hand, there are several hospitals where appointing a doctor is difficult and they have instead appointed pharmacists or nurses. These people are given the title of Maintenance Managers,

  2) ME technical personnel and person in-charge of management at site: An anaesthetic nurse to carry out inventory management and regular maintenance/inspection, etc. may be appointed. This person is trained on the basic medical equipment technology and spare parts replacement techniques. This aims to upgrade the personnel to correspond to the level of ‘Clinical Engineer’ for the future,

  3) Technical assistant: Assists the above technical personnel and works on site.
Note 2.9 In Cambodia for example, NMEW first conducted a seminar on medical equipment management in April 2002 targeting mainly directors of national/referral hospitals and of provincial health departments. At this seminar, facilitators and resource persons were mainly doctors and hospital managers who were already involved in medical equipment management. Based on this, NMEW conducted the first workshop on medical equipment management in March 2003 in co-operation with JICA. In this workshop, further improvement in the management of medical equipment in Cambodia (based on the life cycle approach as well as a report of NMEW's activities) was discussed.

At this workshop, a lot of ideas and opinions were expressed to find a way forward regarding MMS in Cambodia. The table below shows workshop achievement. These are part of the ideas and opinions expressed by the participants regarding annual activities of NMEW.

Table Evaluation, findings and recommendations on NMEW carried out by the workshop participants

<table>
<thead>
<tr>
<th>Overall Evaluation</th>
<th>Problems</th>
<th>Recommendations</th>
</tr>
</thead>
<tbody>
<tr>
<td>- The existence of NMEW is important for healthcare service.</td>
<td>- NMEW does not respond to all service requests.</td>
<td>- Conduct training on maintenance and repair at provincial level.</td>
</tr>
<tr>
<td>- The existence of NMEW is beneficial for the national and referral hospitals.</td>
<td>- Lack of spare parts</td>
<td>- Establish a Training Centre for medical equipment maintenance and management.</td>
</tr>
<tr>
<td></td>
<td>- Lack of communication</td>
<td>- Provide assistance for setting up an in-house service system in local hospitals.</td>
</tr>
<tr>
<td></td>
<td>- No guidelines or technical manuals for medical equipment</td>
<td>- Help for survey and inventory making.</td>
</tr>
<tr>
<td></td>
<td>- Repair completion level is low.</td>
<td>- Provide technical service at the provincial level.</td>
</tr>
<tr>
<td></td>
<td>- Shortage of human resources</td>
<td>- Strengthen supervisory activities.</td>
</tr>
<tr>
<td></td>
<td>- Lack of budget allocation for maintenance, management and repair in the hospital</td>
<td>- Conduct training to medical equipment operators.</td>
</tr>
<tr>
<td></td>
<td>- It is not clear who bears the above-mentioned budget: MoH, JICA or hospital?</td>
<td>- Locate spare parts suppliers.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>- JICA expert is requested to contribute towards establishing a maintenance and management system.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>- Make action plan for strengthening the function of NMEW.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>- Cooperate with the Medical Equipment Sub-coordinating Committee.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>- Translate equipment instruction manuals to Khmer version.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>- Establish budget allocation for maintenance, repair, and management.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>- Make standardisation list of required medical equipment.</td>
</tr>
</tbody>
</table>

Thus, such seminars and workshops are very effective for dissemination of information on MMS based on the life cycle approach. At this forum, top management ranging from MoH to hospitals came to appreciate that management of medical equipment maintenance should be given priority, as opposed to concentrating on repairs of faulty equipment.

The achievement of this workshop will be used as reference for future workshops. The next workshop to be conducted will deal with needs assessment and medical equipment survey. Follow-up workshops will be conducted based on the achievement of the previous workshop until an action plan of NMEW and national policy on
management of medical equipment is developed by MoH.

Note 2.10 In Afghanistan, the real health administrative system restarted in 2002 after bridging over the war and long civil war. In such a situation, a large amount of medical equipment was being provided by various international donors. The management system for medical equipment, however, was not yet well set up. The Ministry of Public Health (MoPH) began various activities for further improvement of MMS considering this situation.

Workshops on medical equipment management, supported by JICA, have been conducted three times. The objectives of these workshops have been to disseminate ‘the life cycle approach’ and to improve the management of medical equipment from this viewpoint.

The first training workshop on medical equipment management was conducted in October, 2003 at the Central Medical Equipment Workshop of MoPH targeting engineers and technicians (site level). A second training workshop covering almost the same topics was conducted in joint co-operation with JICA and OPM (Oxford Policy Management) in December, 2004. This 2-day workshop targeted maintenance managers and doctors who take charge of medical equipment management in national hospitals located in the capital, Kabul (hospital intermediate level). Two months later, another workshop on medical equipment management targeting MoPH managing personnel and hospital directors of national hospitals in the capital, Kabul, was conducted (hospital top management and MoH management level).

As soon as the training workshop targeting the hospital intermediate class ended, the Drugs and Biomedical Equipment Department of MoPH started carrying out the survey for utilisation of medical equipment including main facilities in national hospitals located in the capital, Kabul. The purpose of the survey was to make an equipment inventory list, which is the basis of life cycle management.

Though some issues have lagged behind in the field of medical equipment management in this country, further development of this field - as well as human resource development - is expected in the future.

Note 2.11 Electrical safety—The most common safety problem with medical equipment that utilises and applies electricity (medical electrical equipment) is an electrical shock. For instance, when we touch old equipment, we may feel the electrical shock. This is as a result of an electric current leaking from the equipment flowing through the body into ground (gross shock). The current value is estimated to be about 1mA, and it is called the leakage current. On the other hand, if a direct current of even 1mA flows through the heart (micro shock), it kills human beings instantly.

Many types of medical equipment connecting directly or indirectly to patient's body by electrodes are used. In addition, electrical safety of medical equipment decreases gradually with the age of the equipment. Therefore, with regular monitoring of this leakage current value, the electrical safety of the equipment should be maintained.

It is, however, difficult to implement the leakage current monitoring system though a commercial type of measuring instruments is available (see Photo below). It is, therefore, necessary to measure at least the insulation resistance for general medical equipment. It can be said that it is an acceptable standard without compromising on electrical safety.

The type and ‘safety limiting current value’ of leakage current are stipulated by the National Standard (JIS in case of Japan) in individual country as well as IEC (International Electro-technical Commission). On the other hand, the safety standard of medical equipment that does not apply electricity is stipulated by ISO (International Standard Organisation).
Example of an Electrical Safety Analyzer: Equipment that measures overall electrical safety parameters for medical equipment as follows:

- Various leakage currents, e.g. enclosure leakage current, protective earth leakage current, patient leakage currents, patient auxiliary current
- Resistance value of protective earth line
- Supply voltage
- Insulation resistance

Note 2.12 The reason is that the equipment supplier submits the invoice of equipment placed inside of package without indicating or showing individual equipment identification. On the other hand, the contents of equipment will be similar to this after the hospital makes an equipment property list. This shows that neither a registration system nor an ID system for individual equipment is completed in most hospitals.

Note 2.13 As for infant incubators in NMCHC for example—In this example, high temperatures in the incubator canopy were recorded in the range between 38-40°C with the safety switch operating normally. Further investigation revealed that the problem had been with the power supply. This arose from one power supply line, but the incubator worked normally when connected to another supply line in the same room. This was difficult to understand, and engineers from the designing company and equipment supplier were involved to help find the cause. However, no reason was found.

As a result of further checking, the ME section discovered that there was “pulse noise” on the AC power supply (see Figure below). This result was brought to the attention of the engineering section of the equipment manufacturer, and they concluded that this pulse noise resulted in adverse effects to the temperature control circuit of the incubator. This conclusion was reported to the designing company, and an attempt to solve this problem by inserting a “pulse noise removal transformer” between the incubator and the power supply was done. However, the source of the noise still remains unknown, though the live issue was solved.

Note 2.14 High-pressure steam steriliser (large-scale)—This consists of a complex structure in which electricity, electronics, mechanics, water circulation and high-pressure steam systems are integrated. This equipment being operated on a 24-hour basis is essential for the hospital to sterilise linen, medical instruments, etc. for use in both the operating room and the ward. If failure occurred, the hospital service would be interrupted or stopped. Regular inspection of this equipment is, therefore, essential. In the Tribhuvan
University Teaching Hospital, Nepal, all six sterilisation units broke down due to inadequate maintenance. The hospital borrowed the sterilising machine from a neighbouring hospital to avoid interrupting or stopping vital services (as of 1996).

**Note 2.15** In NMCHC for example, the EUR is being kept at rate as high as 85-90% after establishing MMS. Table below shows the transition of utilisation rates according to the type of provision in NMCHC.

**Table** Transition of medical equipment utilization rates during five years in NMCHC

<table>
<thead>
<tr>
<th>Fiscal Year</th>
<th>Provided in 1993</th>
<th>Provided in 1997</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Cost basis</td>
<td>Quantity basis</td>
</tr>
<tr>
<td>1998</td>
<td>46%</td>
<td>62%</td>
</tr>
<tr>
<td>1999</td>
<td>84%</td>
<td>85%</td>
</tr>
<tr>
<td>2000</td>
<td>87%</td>
<td>86%</td>
</tr>
<tr>
<td>2001</td>
<td>87%</td>
<td>89%</td>
</tr>
<tr>
<td>2002</td>
<td>87%</td>
<td>89%</td>
</tr>
</tbody>
</table>

This table shows the following things:

- Utilisation of equipment provided in 1993 is 46% on cost basis and 62% on quantity basis in fiscal year 1998. The reason is obvious: measures on maintenance and management were not taken for five years after equipment was provided. Such percentages are estimated to be the average number of the equipment group in the same batch without maintenance five years after having been provided.

In such a situation, NMCHC — JICA technical cooperation facilitated the procurement of necessary accessories/spare parts and establishment/training of the maintenance and management system. As a result, the cost basis of 46% was raised to 84% in fiscal year 1999;

- Equipment provided in 1997 was maintained on a high EUR from the beginning, since the type of equipment was selected by adapting with clinical/operation level at the local site. However, if the maintenance management system did not exist, they would be in the same situation five years later, as the equipment was provided in 1993.

**Note 2.16** Facility running cost—Facility running cost is one of the important elements for rational and economical management of hospital. However, if the maintenance system does not function, necessary data for the costing cannot be generated.

In NMCHC for example, the facility maintenance section exists separate from the ME section. This section carries out daily maintenance and inspection of buildings and hospital plants and systems, and all findings are recorded. In addition to this, the running cost for facility operation every fiscal year is compiled and submitted to the hospital management. The table below shows the running (or operational) cost for NMCHC’s hospital facilities in fiscal year 2002.

**Table** Facility running cost in fiscal year 2002—NMCHC

<table>
<thead>
<tr>
<th>Facility</th>
<th>Consumption</th>
<th>Cost (US$)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 Electric power supply</td>
<td>894,400 kWh</td>
<td>167,700</td>
</tr>
<tr>
<td>2 Emergency generator (Fuel)</td>
<td>2,300 L</td>
<td>776</td>
</tr>
<tr>
<td>3 Water supply</td>
<td>39,561 m³</td>
<td>9,296</td>
</tr>
<tr>
<td>4 Oxygen gas</td>
<td>2,077 cylinders</td>
<td>11,424</td>
</tr>
<tr>
<td>5 Incineration (Fuel)</td>
<td>4,200 L</td>
<td>1,575</td>
</tr>
</tbody>
</table>

Grand total US$ 190,771
Note 2.17 **Non-stocked spare parts**—These are procured as needed. Stock of the following spare parts should not be done or encouraged:

- Back-up battery: e.g. for Defibrillators, Doppler fetus detectors, Infusion pumps, Patient monitors;
- Power battery: for Mobile X-ray equipment;
- Sensor: e.g. for Anaesthesia apparatus, Oxygen analysers, pH meters;
- X-ray tube: for X-ray equipment.

Note that spare parts made of rubber deteriorate easily in high temperature and humidity. It is recommended that they be kept in an air-conditioned storeroom.

Note 2.18 **Stock control for daily consumables**—As an example, stocktaking of filters for infant incubators and giving out sets for infusion pumps should be carried out at least once every three months. However, it is recommended to keep extra stock in developing countries because of difficulties encountered with procurement.

Note 2.19 **MEMC:** The objective of MEMC is to achieve rational and transparent management of medical equipment, and to be involved in monitoring and discussion of better utilisation and management of medical equipment so that accurate and quality healthcare services can be provided. The MEMC has mainly the following functions:

- Safety management;
- Monitoring equipment utilisation;
- Co-ordination between the related sections, particularly the procurement, finance and technical sections;
- Standardisation of equipment maintenance and management;
- Risk management;
- Evaluation of the equipment performance and safety;
- etc.

Formulation of the MEMC at the hospital level may comprise the following stakeholders:

- Managing Director
- Director of Laboratory Services
- Director of Finance
- Director of Nursing
- All Clinical Heads
- Head of Radiology
- Head of Pharmaceutical Services
- Purchasing and Supplies Manager
- Hospital Maintenance Manager
- Head of ME Section
- etc.

At the national level, MEMC comprises the stakeholders corresponding to the above-mentioned examples.

Note 2.20 **Lack of collaboration between ME section and Procurement & Logistics section**—In many developing countries, the collaboration between the ME section and the procurement & logistics section is weak. In such a situation, where necessary spare parts for maintenance cannot be stocked, the ME section cannot perform maintenance cycle management. This is one of the main reasons why the ME section unavoidably selects the repair system, and not the maintenance system for managing equipment (exclude ME sections that persist in their repair systems).

In such a situation, there is still room in which the situation can be improved as follows:

- Because the staff and manager of the procurement and logistics section are not specialists in medical equipment, they do not adequately understand that spare parts...
are necessary for maintaining and inspecting medical equipment. The ME section should understand this;

- The ME section should conduct a seminar or a workshop for managers of procurement & logistics and of the financial section to attend. This will bring better understanding on maintenance cycle management and good communication between the two sections;
- In the ME section, it is clear that spare parts cannot be purchased due to unavailability of budget allocation. However, from a procurement & logistics viewpoint, they are not able to prepare a budget for procurement in the absence of a necessary spare parts list and its prices. The ME section, therefore, should carry out statistics on services performed in the past, and calculate concrete expenditures including spare parts based on this.

In conclusion, the ME section should understand the MMS. This will help to predict and estimate necessary spare parts and materials based on budget allocation for maintenance cycle.

Note 2.21 For instance, MoH of Zambia abolished its central workshop, and instead established two positions, one at the Ministry Headquarters and one at the Central Board of Health (CBoH) to take charge of medical equipment management as shown in the figure below.

```plaintext
MoH
Equipment Analyst
One position

Central Board of Health
Director General

Equipment Specialist
One position

MoH
Equipment Analyst
One position

Decision making for medical equipment management policy

Central Board of Health
Director General

Equipment Specialist
One position

In-house services and existing workshops

Central hospitals: Kitwe, Ndola: 2-4 positions
UTH BMED: 8 technicians
District Hospitals: General technicians each (under planning)
Provincial Health Office -A: One position
Provincial Health Office -Σ- One position

9 provinces

Organisational structure and staff allocation on medical equipment maintenance and management in the Republic of Zambia (as of March, 2005)

MoH takes charge of decision making and policy formulation regarding medical equipment management, whereas CBoH plays a role of policy implementation throughout the country.

UTH, being a National Hospital, has eight technicians headed by a chief technician under the Biomedical Engineering Department (BMED). The main activities are:
- Installation and commissioning of equipment;
Maintenance and repair of medical equipment;
Inventory management;
User training (for UTH staff and staff from other medical institutions and hospitals);
Training of maintenance technicians (for UTH staff and staff from other medical institutions and hospitals);

At the provincial level, there will be one chief technician whose role is to coordinate all districts in the province regarding medical equipment maintenance and management.

At the district level, there will be one technician whose role is to coordinate all health centres in the district regarding medical equipment maintenance and management.

Note 2.22 Position of central workshop in the future—The figure below shows an example of medical equipment administration system in a country. This system is composed of four organisations, i.e., academic, neutral, commercial/industrial and government organisation. Central Workshop becomes an ME administrative agency as a neutral organisation which takes charge of overall administration of medical equipment in the country.

This national administration system for medical equipment adapts an integrated and multidisciplinary approach that takes into consideration the academic, commercial, industrial, standardisation, organisational and national administrative aspects, and contributes to management and development of medical equipment technology in the country. In addition, this system involves comprehensive aspects such as development, design, manufacturing, product examination, sales, usage, maintenance, management, decommissioning and education on medical equipment.

![Diagram of medical equipment administration system](image-url)