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TECHNO- ECONOMIC ASPECTS OF CMMS IN DEVELOPING AND DEVELOPED COUNTRIES

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* IN CAPACITY OF UNIDO CONSULTANT.

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Techno-Economic Aspects of CMMS in Developing and Developed Countries.

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1. Introduction

The Fourth general conference of UNIDO held in Bangkok, Thailand in November 1987 adopted resolution 1, which, inter-alia recommends that UNIDO should "accord special attention to the problems of maintenance of industrial plants and develop programmes for that purpose." I am convinced, that this 2nd Expert Group Meeting on CMMS will certainly endeavour to contribute to this resolution's implementation.

The lack of systematic maintenance, or sometimes in-existance of systematic maintenance has been one of the major factors inhibiting industrial and economic growth in developing countries. Inspite of the fact that this problem has been known, studied and discussed in national and international forums for a long time, no considerable overall progress has been achieved in solving it and thus removing a major obstacle to the industrial development process. In a symposium on maintenance in developing countries, held by UNIDO in Tokyo, Japan, in 1973 it was indicated that the life span of capital equipment was reduced by 30% because of lack of maintenance capacities. The cost arising from their decrease in life span of the plant equipment was then valued to be US $ 5 to 7 billion (other consequential damages arising from indirect costs, such as overhead costs, overtime and increased labour costs, lost production and sales could not even be estimated).

It was as long ago as that (15 years back), when the Metallurgical Branch of UNIDO launched their first project on " Managed Maintenance in Metallurgical Industries" with EISCO here in Egypt, to deal with this challenging issue through CMMS.

The scenario in many industrially developed countries showed negligance and no systematic maintenance management practices, too - e.g. a 1981 United Kingdom Survey in the field of maintenance revealed that in numerous companies maintenance costs reached 25% of plant asset value, no consistent analysis of plant and maintenance performance was made, only 12% of companies surveyed kept systematic maintenance records etc. The awareness of inadequate maintenance management and careful cost considerations (during and/or after the oil crisis) in more tough competition for steel markets have lead, together with the introduction of latest technology (which could not be operated without adequate maintenance at all), to considerable improvements of industrial maintenance practices, the introduction of CMMS in late seventies/early eighties being one of the most contributing factors, among others. The introduction of CMMS in the developed countries was specially accelerated with the advance of relatively inexpensive personal computer/local area network (LAN) distributed CMMS and the wide spread use of micro-processors for plant condition monitoring, e.g. the 1987 Survey of CMMS packages, identified and evaluated more than 40 software packages available on UK market. This clearly illustrates the dynamic development of CMMS market there and widespread CMMS implementation.

UNIDO, in particular the Metallurgical Branch became soon aware of the industrial maintenance management problem (inadequate maintenance being specifically costly for the large capital asset investments into rapidly established steel plants in developing countries) and started in 1972 organisational studies to create due awareness e.g. SIS project in Hungary (Dunaivaros Steelworks), the above mentioned multi-phase CMMS large scale project in Egypt (EISCO, Helwan) followed up by implenentation of CMMS in Czechoslovakia (1978-81, East Slovakian Steelworks, Kosice in co-operation with INORGA), SIS preparatory assistance project for SIDERMEX in Mexico(1985) with follow-up cost sharing project for AHMSA and SICARTSA Steelworks, large scale project on introduction of CMMS into SAIL in India (1986 - Rourkela Steel Plant with follow-up transplant to Bhilai and Bokaro Steelplants), Regional network project for European countries in 1987 and Regional Project for ASEAN countries in 1988. A large scale cost sharing project for People's Republic of China is being planned, starting in 1988 with several other national/regional projects in the pipeline. These pioneering efforts brought positive results of CMMS contribution to maintenance and plant availability improvements. The majority of projects have been associated with international group training programmes, demonstration workshops etc. to enable for a broader exchange of information and dissemination of advanced technical know-how in the multiple fields of CMMS.

In order to rationalise this development process the 1st Expert Group Meeting (EGM) on CMMS was held in 1985 in Prague, Czechoslovakia, under UNIDO auspicies. The 1st. EGM established, inter-alia a Permanent Working Group on CMMS which consequently met in 1986 in Kosice, Czechoslovakia (during the 3rd. UNIDO-CSSR Group Training Programme) to prepare the grounds for the 2nd. EGM in Cairo, Egypt, in co-operation with the Egyptian Iron and Steel Company (EISCO) with the objective to examine further modern trends in CMMS development (e.g. the impact of rapid introduction of Personal Computers), to identify the effective ways of CMMS dissemination to other basic industries and development of human resources/e.g. through national/ subregional/regional centers and networks) and to develop practical recommendations and guidelines for further projects and CMMS implenentation in developing countries using their own experience and resources, together with the latest state-of-art know-how from industrially more developed countries.

2. Economic aspects and justification for CMMS.

Talking about techno-economic aspects and justification for CMMS let us first talk of what maintenance is, maintenance costs factors and profitability function are, since they primarily influence the CMMS justification process. Some define maintenance simply as repair after breakdown(emergency maintenance), others usually include planned maintenance, both preventive and corrective, the former being either fixed time maintenance or condition based maintenance, the latter being further qualified to breakdown versus shutdown maintenance and still others, more advance, include plant condition monitoring into both of these categories (In fact, the trend for use of condition monitoring, particularly with microprocessor systems, offers major factor in the increase in reliability, safety and availability of plant equipment). Yet aspects of maintenance go far beyond these definitions - maintenance function is considered to be the factor of profitability, quality and efficiency of the enterprise - the effects of maintenance costs upon total production costs being usually described by the well simplified costs optimization curve (see Fig.1) and/or more realistic optimum frequency interval curve(see Fig.2) or, in a long-term justification view, the function of optimizing the efficiency of capital investment through a real increase in the availability of capital equipment and through adequate conservation method at a total minimum costs. To study the whole life of capital equipment, often the U equipment failure profile curve is used (see Fig.3).

In practical situations, however, the maintenance direct costs(basic resources - manpower, materials and equipment) and indirect costs(losses of production, sales, shorter life span of equipment etc.) as well as corresponding benefits/improved plant availability, reduced operating costs, improved reliability through fewer breakdowns, increased product quality, operational life etc.) become part of the overall Maintenance Management cycle (see fig.4 and 5). Hence the maintenance function should include all stages of capital investment and plant management - project investment study and planning, negotiation and procurement of capital assets, their operation, utilisation and actual maintenance, design and improvement (redesign) and last but not least the equipment phase-out (alternative exploitation and ultimate replacement).

The introduction of CMMS contributed significantly to the improvement of the decision making in the overall maintenance management cycle (this was shown and spelt-out clearly during the 1st EGM) depending, of-course, on the scope of computerization. The overall functional structure of CMMS suitable to support maintenance improvement was roughly defined to include the following main areas:

1. Preventive Maintenance and Repair Planning.
   - Plant register
   - Preventive maintenance planning.
   - Repair planning and shutdown planning
   - Maintenance work order generation.
   - Maintenance work order scheduling and progressing.
   - Material requirement planning.
   - Manpower requirements planning
   - Maintenance cost planning.
2. Maintenance jobs planning.
   - Job catalogue
   - Job allocation
   - Planning and job scheduling.
   - Releasing maintenance job
   - Despatching and job execution monitoring
   - Rescheduling.
3. Spare parts Requirements Planning.
   - Spare parts catalogue
   - Requirements planning
   - Parts and materials allocation
   - Inventory records keeping
   - Inventory control
   - Inventory receipts and disbursement.
4. Spare parts Inventory and Purchase Control
   - Make-buy decision making
   - Purchase requisition
   - Purchase order generation
   - Vendor data update
   - Follow-up.

5. Spare parts Manufacturing and Recondition Planning and Control.
   - Drawings.
   - Bills of material
   - Routing operation
   - Work centres
   - Capacity planning and operations scheduling.
   - Work order progressing
   - Shop-floor monitoring and control
6. Maintenance Monitoring and History
   - Equipment lay-off monitoring.
   - Maintenance orders monitoring.
   - Job status reporting.
   - Maintenance history analysis.
   - Manpower loading and efficiency.
   - Maintenance costs monitoring.

Let us try now to specify in more details which improvements and benefits can be obtained through the CMMS implementation with the above outlined structure.

The potential benefits of CMMS depend to certain degree on management objectives and specific constraints and situations that it is designed around and the existing even non-existing systems it replaces or complements. Based on these, the major CMMS benefits are:

1. Increased production facilities(plant) availability.
2. Increased manpower utilisation and efficiency.
3. Reduced spare parts and materials stock.
4. Reduction of direct and indirect production costs.
5. Improved financial control.
6. Other (miscellaneous) benefits and improvements (so called intangibles).

Let us try now to explain in more details the above both tangible and intangible benefits under the above mentioned headings(which may be easily related to management objectives and priorities, although a different categorization and/or overlapping will always be possible) and illustrate them with some illustrative figures based on practical CMMS implementations both in developed and developing countries.

1. Increased Production Facilities(Plant) availability.

- Reducing the number of breakdowns through
  * Equipment monitoring (scheduled inspections, measurements,checks during idle time).
  * Historical data processing (Preventive operations, optimum/cost justified planned preventive maintenance frequencies,verification check lists etc.).
  * Downtime analysis (identification, analysis and correction of defects, rescheduling of repairs or replacements).
- Decreasing machine idle time
  * Systematic work preparation
  * workorders grouping and scheduling
  * fast selection and despatching (work orders ready in case of idle time/ shutdown)
  * precisely known capacity required.
  * quicker fault diagnosis and evaluation of remedies.
- Co-ordination of Production and Maintenance Planning.
  * Co-ordination of production and maintenance work schedules (considering various impact options upon the whole range of inter-related production facilities and processes).
  * recognition of critical work and faster response to the higher priority assigned work.
  * Improved compatibility with various other department.

- Replacement decision making and strategy on a rational basis.
  * continuous condition monitoring
  * analytic information on assemblies and plant items and/or their groups.
  * improved plant condition due to reduced breakdown frequency.
  * effects of different criteria may be simulated and evaluated to determine the equipment life span, other possible exploitation and phase out costs etc.

2. <u>Increased Manpower Utilisation and Efficiency.</u>

- Reducing nonproductive time due to the:
  * planning jobs against known availability of plant and spares (precise work order instructions, complete and timely availability of spare parts and tools).
  * Setting standard times for jobs (with monitoring and up-date based on job execution feed back).
  * Reducing the manpower (workers) idle and waiting time(waiting for spares, waiting for access, waiting for another maintenance worker, discussing symptoms and remedies, organising lifting tackle, transport).
  * Reducing workers travel time (data retrieval without travelling, optimizing time between job assignments through balanced capacity planning).
  * Reducing complexity of work and volume of clerical work, reducing complexity of work and job order generation through automatic copy of work order and job card documents, simple access to catalogues,manuals and drawings, simple reporting and data retrieval.
- Improving manpower performance by:
  * control and reconciliation of job hours to clock hours(better supervisory control, better scheduling through arranging the outstanding work in lists allowing alternative options to be considered before finalising the schedule.
  * exploiting cummulative experience and having the ability to respond quickly to changes and emergency situations.
  * timely identification of limited resources required to progress the work.

* identification and rectification of common defects.
* comparison of manpower utilisation in order to identify skill requirements and training needs and monitor training/personnel policies.

3. <u>Reduced spare parts and materials stock.</u>

- Decreasing average stock levels
  * decreasing minimum stock and number of replenishment orders (immediate record of movements, known maximum lead time, deferred stock replenishment).
  * decreasing the number out-of-stock situations.
  * stock level check at each disbursement.
  * improved stock requirements forecast.
  * timely reservation of spare parts.
  * identification of high value and high usage items.
  * eliminating "dead" and low turnover items.
  * suppressing excess or obsolete parts.
  * standardization(up-dated "where used" lists substitute part stock movement analysis, concentration of purchasing effort into major items and analysis of alternative vendors, alternative items and components.
  * identification of outstanding purchase orders and thus non-redundancy of orders.
- Decreasing spare parts usage
  * suppressing 'hidden stock'
  * increasing return
  * automatic check of unused or repaired parts to be returned.
  * timely decision for repair and/or reconditioning.
- Introduction of coding which allows links with maintenance materials requirements planning and rationalisation of stock.
- reduced clerical effort through replacement of manual records system with on-line receipts and disbursement as well as inquiries.
- Reduction of the administration of information processed between the stocks and purchasing.
- Improved overall accuracy and relevance of data resulting in reduced time spent reconciling stock checks and carrying stock management.
- reduction of overall costs of materials carrying and handling (lower stores costs per unit maintained.)

4. <u>Reduction in Direct and Indirect production costs.</u>

- Extended plant/equipment life.
- Increased production volume and yield.
- Improved product quality.
- Reduction in product rectification and other finishing costs.
- Reduced energy costs through better equipment deficiency identification and energy control.
- Reduced idle time (less non-productive costs) and reduced unit operation costs.
- Effective capital investment policies.

5. <u>Improved Financial Control.</u>

- Financial Control (understanding of costs of deviations from the calculated optimum - whether "overmaintenance is more costly than "under maintenance" and vice-versa)
- Possibility to calculate the optimum trade off point (internal) at which maintenance becomes effective and specify (in terms of costs) each of the contributing factors.
- Assess both the direct(manpower, materials, equipments) and indirect costs(penalties associated with doing maintenance).
- Assess the impact of any potential modification to the design, operational practices, staffing levels, etc. in direct $ per hour terms (estimates versus systematic financial calculations; majority of engineering parameters can be reduced to financial measurements, too)
- Budget control and cost analysis (per cost centres, equipments, maintenance centers, manpower etc.)
- Life cycle costing (feed back of the total maintenance hours and costs, estimated downtime costs in terms of production loss, addition of materials affecting total salvation of the assets, depreciation factor over life cycle)
- Comparison of costs of various renewal policies for justification of new equipment replacement.

6. <u>Other Intangible benefits and Improvements.</u>

- Improved management reporting and better 'creative' use of managerial skills.
- Improved communication and feed back.
- Improved accuracy and timeliness of information.
- Handling large volumes of data without losses.
- Improved conditions for full managerial control

- Improved discipline and motivation
- Improved 'Shine', functional status(customer impression, staff morale and confidence.)
- Compliance with absolute requirements (e.g. Government safety regulations, legal etc).
- Improved co-ordination between departments.
- Improved customer service and satisfaction etc.

To illustrate the above mentioned benefits, let us describe now several CMMS case studies from Iron and Steel Industries as well as more general CMMS survey results from both more developed and developing countries.

Very good tangible improvements were achieved by INLAND STEEL, the 7th. largest US steel maker with 7 Mil.tons of saleable products (Indiana Harbour Integrated Steel Works).

10% increase in plant availability

10% increase of labour productity in maintenance.

10% reduction of spare parts inventories.

The CMMS was developed in the general integrated version by company's own EDP and maintenance personnel over extremely short period of 1.5 years using IBM maintenance computer dual processor system(6 Megabyte memory each) and the network of about 600 terminals. The whole system was implemented throughout the works.

An American study of CMMS benefits in various sectors of industries indicating CMMS impact on unit costs revealed the following:

Reduced down time by	2	-	10%
Increased Manpower utilization and productivity by	10	-	15%
Improved product quality by (reduction in scrap/waste.)	1	-	3%
Energy savings by	1	-	5%
Deferred capital replacement	10	-	15%

In Japan, the Keihin Works of Nippon Kokan belong to the most modern steel works with the annual output of 5.5 mil.tons. The ratio of maintenance cost to turnover being 7-8%. The major objective of CMMS was to reduce maintenance cost (the maintenance manpower being 20% of total manpower). Whilst the total investment into CMMS implementation was yen. 700 mil. the resulting annual decrease of maintenance cost was yen.500 mil. Out of this, maintenance labour was reduced by 3.2% with additional improvement of standardization in planning and reduction of paperwork. In general, the CMMS in Japanese iron and steel industries is oriented more towards "Intangibles" due to their high degree of automation, quality and productivity already achieved(e.g. Nagoya Works of NSC, where the main objectives of CMMS were planning standardization and efficient coordination of interrelated departments and processes).

Very conservative tangible benefits(based on survey of United Kingdom CMMS end users) were reported as"guidelines" for CMMS justification process:

Increased plant availability by	2%
Increased manpower productivity by	3%
Reduction of stock levels by	5%
Energy savings by	5%

An interesting analysis of economic significance of CMMS was reported in a Swedish survey of 55 industrial companies, assessing the economic significance of various factors and the extent to which CMMS influences these(for the assessment a scale from 1 to 5 was used to indicate little or great influence, respectively; A indicating the importance of the factor to the company, B indicating possibility to influence these factors by CMMS, see table below)

	A	B	A * B
Plant availability	4.7	4.8	22.5
Quality improvement	4.7	3.2	15.0
Tied-up Capital	4.0	2.8	11.2
Delivery time	4.6	3.4	15.7
Utilisation of resources.	3.0	2.5	7.4
Safety aspects	4.5	4.0	18.0

Shell International Petroleum(Netherlands) described the following major benefit achievements through CMMS introduction:

Increased Plant availability by	2%
Manpower cost savings by	2.5% - 7%
Materials cost savings by	2.5% - 7%

Talking about actual benefits of CMMS introduced as a typical UNIDO pilot project in a developing country let us take the example of EISCO Helwan, ARE, which introduced system in two phases (basic system during 1973-81, extended system including production control and planning functions during 1981-86). The following is the comparison of the results achieved during phase 1:

Results	1979	1981
Total production	465,000 T	1130,000 T
Production workers	18,000	15,200
Maintenance workers	8,000	9,600
Production of spares	6,000	34,000
Consumption of spares/ton	14-22 KG	8-12 KG
Total inventory(£ mil)	4.7	0.27
No. of inventory items	132,000	154,000
Manhours maintenance (per month)	80,000	65,000
Average meantime between failures	12 hrs.	185 hours
Total profit of plant(£ mil.)	9.0	34.0
No. of computer staff	28	135

Another illustration case study of UNIDO large scale project implementation was introduction of CMMS in East Slovakian Steelworks, Košice (4 Mil. ton integrated steelworks), Czechoslovakia. The annual tangible savings achieved through system implementation can be summarized as follows:

FACTOR	CS crowns (thousands)	%
- Savings due to the lower downtimes of key production facilities.	9,239	14.6
- Savings due to the lower inventory levels of spare parts.	11,000	17.4
- Savings due to the lower imports of spare parts (foreign exchange)	18,500	29.2
- Savings due to the increased productivity of standardized assembly repair (150-160 employees).	12,400	19.6
- Saving due to the increased volume of assemblies and spare parts reconditioning.	6,880	10.8
- Savings due to the increased facility loading in the spare parts manufacture - i.e. shops.	1,360	2.2
- Savings due to the improved planning of repairs and manpower utilisation (90 - 95 employees)	3,700	5.8
- Savings due to the lower rescheduling of maintenance jobs and transportation times.	240	0.4
Total annual savings:	63,319	100.0

Considering the overall calculated costs of CS Crowns 115,678 million for CMMS development, routine operation and maintenance within socalled "economic life" of the system (i.e. period 1979-1989) and the corresponding total savings of CS Crowns 296.114 million stemming from the gradual system implementation and improvement during that period (for illustration, see the total annual savings above) the investment return ratio (i.e. economic justification) is approximately 3 years, i.e. the indicator of economic effectiveness per one CS crown (as used in CSSR for economic justification of computer systems applications) is thus 296,114/ 115,678 = 2.56 crowns, a value fully justified for such a computer application project.

Another interesting example is the CMMS benefits study for two major SIDERMEX steel plants in Mexico (AHMSA,Monclova - 3 Mil.tons plant, SICARTSA, Lazaro Cardenas, 1 mil.tons plant) under UNIDO SIS project in 1985. The following major factor/benefits were identified and estimated during the study:

Major factor	SICARTSA	AHMSA
* Increased plant availability.	8,910.00	22,027.00
* Increased manpower productivity.	454.01	1,108.50
* Spare parts and material inventories savings.	412.90	2,508.25
* Spare parts and assemblies repair and manufacture.	241.90	369.60
Total Est. Savings. (in Mil. Pesos)	10,018.81	26,013.35

Estimated % of benefits

1. Production equipment.		
* Increased plant availability	10%	16%
* Reduction of breakdowns	40%	45%
2. Maintenance manpower.		
* Better scheduling	8%	16%
* Better SP availability	18%	10%
* Lower subcontracting	10%	10%
* Overall productivity increase	20%	35%
3. Spare parts and materials inventories.		
* Reduction of stock levels	10%	24%
* Reduction of number of SP	8%	13%
* Reduction of warehouse cost	2.5%	11%
* Overall material savings	4%	5%
4. Spare parts repairs and manufacture.		
* Increased production of SP and assemblies.	25%	25%
* Increased volume of reconditioned spare parts and assemblies.	11%	10%
* Reduction of SP imports	10%	25%

From the above examples of CMMS case studies it is apparent that each CMMS project should be subject of a thorough justification based on a cost evaluation management audit and/or feasibility study, showing the improved effectiveness and efficiency with the existing resources. The comparison of the benefits to be achieved and costs associated with CMMS introduction and operation over a period of time and thus the assessment of economic effectiveness of such an investment project should be part of a "justification report" to be approved by the company management and/or respective Government Supervisory authorities.

So far the benefits of CMMS were described. Let us, then, also consider <u>costs</u> that should be assessed, in the justification process. These should include the following:

1. Costs for the management audit study of CMMS objectives, specification of necessary procedures, areas for possible improvements, priorities etc) which can be carried out by the company's internal management Services experienced staff, external consultants or UN experts (e.g. through a SIS project)

2. Capital costs of computer hardware. These will include, inter-alia, central processor unit (units), central memory, back-up storage

(disks, tapes), terminals, printers and other peripherals. These costs will depend on hardware configuration proposed-main-frame computer system , minicomputer system, personal computer system and/or their local area network. Single versus multiuser configuration, size of network, size of company, plant layout, shopfloor terminal access, existing and required communications, (modems, lines) volume of data/ existing and required and future envisaged computer applications, Government import/customs policies, etc. Besides these major capital hardware costs, additional costs for installation, power supply stabilizers, aircondition, renovation of office space (terminal cells) suitable furniture, cabinets and hardware maintenance costs should be also considered.

3. CMMS software programmes development and/or purchase costs. Actually a number of options is available nowadays - CMMS development by own staff, CMMS development by outside subcontractor, purchase of a standard package, joint CMMS development effort with subcontractor, modification of a standard package by own staff, modification of a standard package by the vendor, and various combinations of above. The cost of

of the software will usually depend on the variant chosen, scope of CMMS and its functions, size of application, generality and modularity of the software, user friendliness, dependancy on particular hardware, systems software (Database Management system, programming language to be used) etc. The choice of appropriate option and/or combination depends on a large number of factors and therefore a thorough appraisal should be made (see later in part 3).

4. So called "hidden costs", these including management input and assistance in the proposals, system design and development and implementation, time and manpower needed for data collection/ data entry and system loading, time to make system operational (implementation-final runs, testing etc.) and time and costs of required training and documentation (both EDP and maintenance personnel.)

Actually, CMMS justification should be a continuous process, starting with the above mentioned fact finding (or mapping of current situation), feasibility study and project proposal, project costs monitoring, post-implementation audits which would evaluate the benefits and thus useful comparison between original estimates and actual figures could be achieved.

To illustrate several of many various possible approaches for the justification process, let us assume for the sake of simplicity, that only hardware and software cost are considered in the following hypothetical examples:

Example. 1

i)	Downtime costs before CMMS introduction.	US $	1,500,000
ii)	Downtime costs after CMMS introduction.	US $	1,350,000
iii)	Savings achieved through CMMS i.e. 10% of original downtime costs (i)	US $	150,000
iv)	Costs of PC hardware	US $	8,000
v)	Cost of CMMS software	US $	19,000
vi)	Total costs for CMMS	US $	27,000
vii)	Assume 3 years amortization (annual depreciation)	US $	9,000
	Then real annual savings due to CMMS for the enterprise are	US$	141,000

Example 2.

i) Estimated maintenance labour costs.	US $	900,000
ii) Estimated maintenance material costs.	US $	400,000
iii) Estimated downtime costs	US $	300,000
Total cost	US $	1,600,000
iv) Estimated saving through CMMS 10%	US $	160,000
v) Costs of PC hardware	US $	8,000
vi) Cost of CMMS software	US $	19,000
vii) Total costs for CMMS	US $	27,000
viii) Assume 3 years amortization (annual depreciation)	US $	9,000
Then real annual saving due to CMMS for the enterprise are	US $	151,000

3. Computer hardware and software for CMMS .

CMMS consists principally of the application software (which supports selected computerized maintenance functions as discussed in the previous part) written in a particular programming language (COBOL, BASIC, C language, and various 4th. generation "user friendly" programme languages report/screen generators), the computer and communications hardware (central processor unit, main memory or RAM, back-up storage media, data transmission processors/controllers, modems, com. lines, terminals, also usually called VDU - visual display units and classical peripherals (printers, reader, scanners etc.) and systems software, i.e. operating system and other various housekeeping software, as data bank manager etc.

The size of the organisation, experience with computers, available financial and skilled manpower resources, mode of operations capture and data availability, CMMS objectives etc. influence the total hardware computer configuration. CMMS started their development and implementation using central " mainframe " computer with terminal network (the socalled corporate multidisciplinary mainframe). In the beginning of eighties, the computer market launched much less expensive micro and mini-computers which enabled rapid introduction of CMMS to medium and small scale industries in developed countries, based on single terminal or multiterminal and single processor or multiprocessor (local area network) computer hardware configurations installations. This trend was reflected in large organisations too - many 'dissatisfied users' having acquired basic skills with personal computers initiated rapid development of "distributed" systems, the ultimate result now being, however, move away from these stand alone systems to large "super" multi-processor central systems with effective central EDP Dept. overheads, fast communications and guaranteed on-line system and data availability. The use of micros (or socalled professional personal computers) and minis (although nowadays the frontier between these two categories is diminishing), provides a large potential for CMMS introduction to small scale and medium scale industries of developing countries due to the low costs of hardware and relatively inexpensive standard CMMS general software packages (in particular using the advantages of centralized development of skilled resources and dissemination of know-how, through regional/subregional network of co-operating organisations.)

The essential characteristics and parameters of the above mentioned computer hardware systems to support CMMS are as follows:

1. Micro (personal) computer systems
   - 8 bit or 16 bit processor or even 32 bit processor (depending on the latest model(e.g. the IBM Personal System 2 model 80 is based on 16 or 32 bit boards with 80386 processor speed up to 20 MHz)

- RAM (internal memory) standard size 128 or 512 Kbyles (IBM personal system 2 now provides standard RAM from 640 K bytes - 2 megabytes).
- Floppy / hard dish drives (one or two floppies with hard disks upto 20-100 megabytes).
- Limited number of terminals(usually single user system, maximum 4-8 terminals)
- Standard Operating system and language, limited graphics.
- Transportable application programmes
- Cost range US $ 4,000 - 40,000.

2. Mini-computer systems
   - 16 bit or 32 bit processor
   - RAM 512 K byles and plus
   - fixed/removable hard disk drives
   - 8 and plus terminals and printers (often with possibility of link with PC Local Area Network.
   - Standard or non-standard operating system with archiving facilities.
   - Cost range US $ 40,000 - 140,000

3. Main-frame computer systems.
   - 1 Megabyte and plus main memory (for larger CMMS 6-12 Megabytes memory modules are required due to large house-keeping overheads).
   - extremely powerful processing (usually several processors - also for back-up reasons) with multi-sharing of resources.

- terminal network transmission control using special purpose processors.
- 200 Megabytes and plus hard disk drives.
- non-standard and highly sophisticated operating systems and full range of programming languages including user friendly 4th. generation programming languages.
- application programmes hardware and software dependent.
- cost range US $ 140,000 and plus

For illustrative examples of these 3 major types of CMMS computer hardware configurations, see figures 7, 8 and 9.

The required computer hardware configuration depends on a number of factors as mentioned above. Nevertheless, the following simple hardware purchasing rules are recommended to be used;

- examine the CMMS application software requirements first.
- never buy the first (new machine) but rather already established machine.
- do not be impressed by system sophistication and gimmics.
- observe carefully government import policies on both the computer, periferals and spare parts.
- ensure it is upwards upgradable as well as extendable to a multi-terminal system and compatible with existing system (if necessary).

- compare total costs of an enhanced system at the outset (price of enhancement of peripherals).
- do not keep waiting for prices to drop.
- consider that a good maintenance support (both hardware and systems software is essential).
- make sure you can add disk capacities, com. lines etc,
- do not save on the quality of the peripherals.

The computer hardware configuration has a considerable impact on CMMS functions and their implementation and vice-versa. From this viewpoint stem CMMS software requirements and features that can be summarized under the following headings:

- Systems functions and structure
- Modularity and integrity
- generality (dependance on particular hardware and systems software)
- Flexibility and adaptibility.
- Transportability of both application software and data
- User friendliness
- System documentation

Having specified the CMMS functions and requirements and resources available to meet maintenance management objectives there are essentially 4 approaches to the acquisition of CMMS software:

1. Own 'in house' development by joint effort of EDP and maintenance departments (which is usually time consuming)

2. Development by an outside party (software house, consultancy firm) and joint implementation (which is usually cost consuming)

3. Purchase of a suitable package and its modification in co-operation with the vendor (software house, large end user in similar industrial sector, hardware vendor)

4. Purchase and adoption of a standard package (which requires changing of local procedures and organisation to suit the requirements of the package)

Although theoretically approach ad 1) i.e. own development should bring most satisfactory results due to the familiarity with procedures and environment, it is usually time-consuming (there are large steelworks in developed countries, where, inspite of 10 years' effort, the CMMS has not been fully implemented yet), software needs extensive validition (local bias), the documentation may not be adequate and in particular, the software support is inadequate. This approach is apparently not feasible for developing country. The same holds practically for ad 2) where significantly higher cost arise and the client is often "overdependant" on software vendor and sometimes is not able to continue smooth CMMS operation and maintenance due to the lack of experience and/or adequate training, fluctuating of skilled manpower, etc. The latter 2 approaches have become most feasible these days, in particular with wide range of available packages, and less expensive hardware. The following factors should be considered in the CMMS software appraisal and package evaluation:

- CMMS functions included
- Software imbodying the functionality should conform to computer hardware strategy prevailing in the organisation.
- computer type and memory size, storage required by the system and terminal network.
- Operating system and data base management system used
- communication abilities.
- software price and its structure (basic fee, licencing, service support, training etc.)
- evaluate software maintenance available (bug fixing, new releases, maintenance charges)
- validate the software through the demonstration and visit to other installations.
- study the level and quality of software documentation.

- establish whether the software is locked or unlocked / source deck should be provided.
- establish viability of data transfer, how all the communication will be handled (hardware or software solution.)

Actually, many of these factors can be advantageously used to specify your organisation's further needs and check the feasibility of your system specification and precondition for CMMS introduction.

4. Pre-conditions of introduction of CMMS

For the successful introduction of CMMS in both developing and developed countries certain basic conditions are required to support a new maintenance management and planning system involving computerization. They could be generally summarised as follows on the enterprise level:

- positive management attitude and clear objectives on both senior and line management levels.
- Basic planning functions and appropriate planning staff.
- Basic administrative procedures for work requests, work orders, and materials and spare parts requisition.

- preventive maintenance routines and job descriptions.
- Equipment and spare parts catalogues and documentation.
- Availability of valid data, history and statistics.
- Correct climate of the shopfloor work force.
- suitable organisational structure.
- availability of basic skills in both industrial maintenance and informatics (basic "computer culture")
- support of Government counterpart authorities.
- Existance of domestic resources for hardware and software maintenance.
- existance of training opportunities in EDP field.
- availability and/or potential access to financial resources for the procurement/development of CMMS software, hardware and training.

This list will, of course, never be complete and also specific factors evaluated in the fact-finding/feasibility study (justification process) and those mentioned in the CMMS hardware and software evaluation should be carefully observed. On the other hand, not all of the pre-conditions mentioned here are an absolute "must". Some of them, depending on the specific, local situation may be overcome and alternative solutions can be found. In fact, in case of the UNIDO CMMS project, they are usually assessed through fact-finding and diagnostics missions and various alternative proposals are recommended based on the mission findings and observations and discussions with both enterprise and Government authorities. This particularly holds for regional projects, where usually not all participating industrial organisations can usually meet the preconditions for successful CMMS introduction. Therefore, special organisations/institutions (Centres) which have necessary infrastructure and know-how and skills and facilities to assist smaller enterprises are selected as national "focal points" to which the participating enterprises in the country are linked. Moreover, the various national focal point institutions (centers) in the region/subregion can support themselves in the selected areas of CMMS development, exchange of know-how and enable the interested enterprises on national level to meet the preconditions (e.g. through specialized training, technical workshops, advisory services, Government and/or UN financial support etc). Usually the most capable focal point of the regional network (that meets majority of the above-mentioned pre-conditions and has leading role capability) is selected as the regional network leading centre, responsible for the overall coordination and support of CMMS development and implementation. For an illustrative example of such a regional network, see Figure 10, depicting the structure of European regional project for PC based CMMS (RER/87/036). In fact, UNIDO provides through preparatory assistance projects required technical assistance to assess and create necessary conditions for the CMMS introduction, including the support of Government and UN authorities to raise the necessary funding on both national and regional levels.

5. Recommendations for CMMS Introduction and advanced concepts to be used for CMMS.

First of all, the maintenance function to be computerized should include all stages of capital investment from planning, procurement, erection to operation, maintenance, design improvement, phase out and replacement. This concept, also considering life cycle costing is often referred to as Teratechnology concept i.e. the multidisciplinary approach.

Each CMMS project should be subject of a thorough justification based on costs and benefits analysis and/or feasibility study which would compare the estimates of costs and benefits associated with CMMS over a period time, i.e. assessment of economic effectiveness as an investment project should be part of the justification report. CMMS justification should be a continuous process, starting with the fact-finding, feasibility study and project proposal, involving project actual costs monitoring and ending with post-implementation audit which would evaluate finally the benefits and effectiveness achieved as well as identify future possible improvements and strategies for their developments.

Benefits and cost evaluation might follow the checklists given in part 2 of this paper, providing more detailed analysis under appropriate headings, in particular increased plant availability, increased manpower utilization and efficiency, reduced spare parts and materials stocks, improved financial control and production costs and other tangible and intangible factors (e.g. energy monitoring and savings, improved spare parts manufacture and reconditioning etc.) Generally, the following % of estimated savings could be used in developing countries as guidelines:

Plant availability	5 - 15%
Manpower utilisation	8 - 20%
Reduced stocks	2 - 20%
Spare parts manufacture	10-25%
Energy savings	1 - 5%

The advanced costing concepts (so called "Anlagen wirtschaft" as introduced by German economists) take into consideration the trade-off direct maintenance costs and downtime costs in relation to capital costs (amortization) and production costs in all various stages of the life cycle as well as in relation to other enterprise commercial, purchasing, financial and personnel functions. Such an integrated approach is, however difficult for the implementation in numerous developing countries, due to the specific prevailing conditions (e.g. lack of foreign exchange, Government sector policies etc.)

CMMS software requirements should be evaluated taking into account the system maintenance functions and structure, generality, modularity and integrity, flexibility and adaptibility, transportability, user friendliness and the resources available (financial, skilled maintenance and EDP manpower, hardware etc), and the CMMS software package appraisal rules as provided in the check list in the paper. Careful attention should be paid to the appropriate approach to the acquisition of CMMS as mentioned in the paper, too (4 basic approaches with their possible combinations).

The same practically holds for hardware computer configuration for CMMS, this depending on the existing resources, size of organisation, CMMS functions and objectives, data availability and capture, mode of operation etc. The hardware purchasing rules evaluation as given in the paper is recommended to be followed. At this particular point it should be noted how the development of inexpensive micro (personnel) computer systems give a "green signal" to CMMS introduction for small and medium scale industries in developing countries. Beside their price and possibility of application of wide range of CMMS software packages, they can also provide the possibilities for performing local specialised functions(sometimes out of the scope of the package) using spreadsheets, editors, data bases etc. and their use as intelligent terminals linked to the main frame computer of focal point institution or local area network.

The preconditions for successful introduction of CMMS are clearly spelled out in the part 4 of the paper. It should be noted, however, that a number of them can be overcome through adequate selection of CMMS software acquisition (e.g. use standard package when no proper maintenance procedures are used - this will help to establish them), use of UN and Government assistance to acquire skills and resources required (e.g. the establishment of regional, subregional networks with focal point institutions) etc.

The implementation of CMMS should be based on a well coordinated phasing of CMMS functions to be introduced and the overall project work plan both in time and physical sites. Not always is the most critical maintenance plant area suitable to start computerisation with. A careful selection of pilot implementation area should be made using as criteria the pre-conditions listed in this paper (eg. data availability, data collection and system loading, end users cooperation, suitable timing etc.). A special attention must be paid to the coordination of system testing, terminals installation and user training. The transfer from the manual system to the computerised one should be gradual in order to allow both end user and EDP staff to get used to the using and running of the system, particularly in the on-line mode of operation of larger CMMS. For each installation one person should be given responsibility for system operation which also incorporates adequate procedures for system back-up. Sufficient programming capacities (20-30 % of development capacities) should be assigned for both implementation and post-implementation period.

As mentioned earlier, during the post-implementation period new improvements can be gradually introduced, e.g. use of modern concepts as plant condition monitoring using microprocessors, reliability analysis, expert systems for technical diagnostics, links to CIM, PERT, operational research methods (e.g. for simulation of maintenance/production plans coordination, failure prediction), CAD (Computer Aided Design) systems to link with drawings, design modification, documentation etc. as well as modern maintenance strategies like the above mentioned teratechnology, logistics engineering, total productive maintenance (the famous Japanese concept introducing preventive maintenance with all employees participating) and others. The future field of such improvements will be broad enough to challenge our resources, skills and professional courage to continuously innovate.

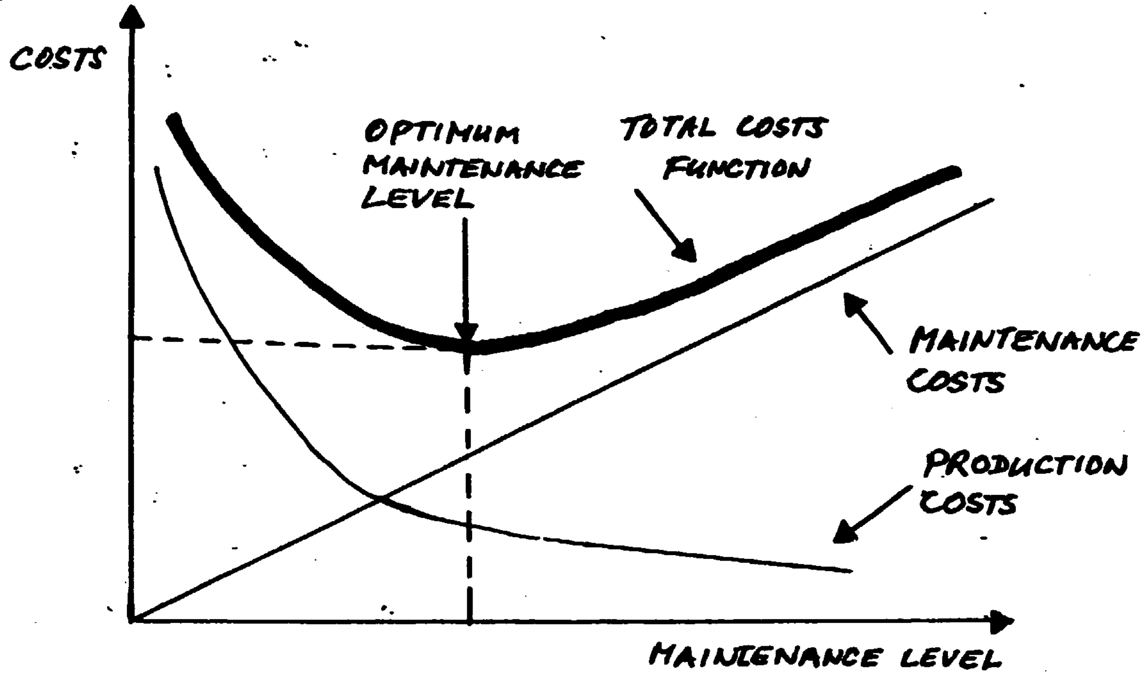


FIG. 1 MAINTENANCE VERSUS PRODUCTION COSTS

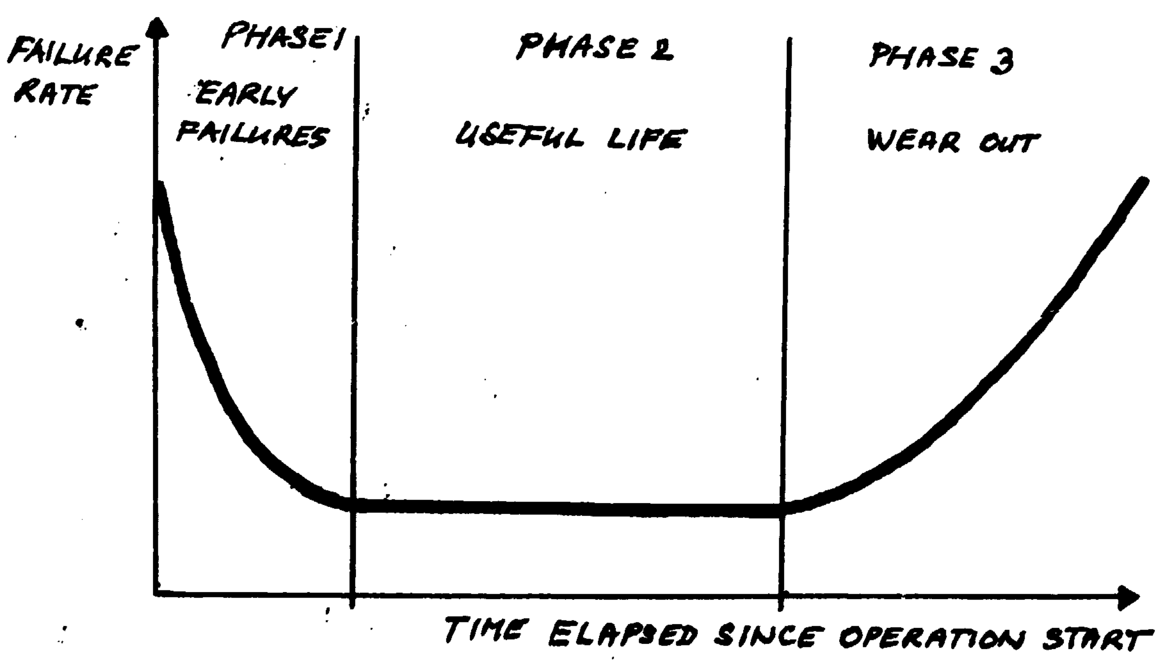


FIG. 3 "U" LIFE CYCLE CURVE

OPTIMIZATION - THROUGH COST CONTROL (ANALYSIS OF A SPECIFIC MAINTENANCE ROUTINE ON A SPECIFIC PLANT FACILITY/EQUIPMENT)

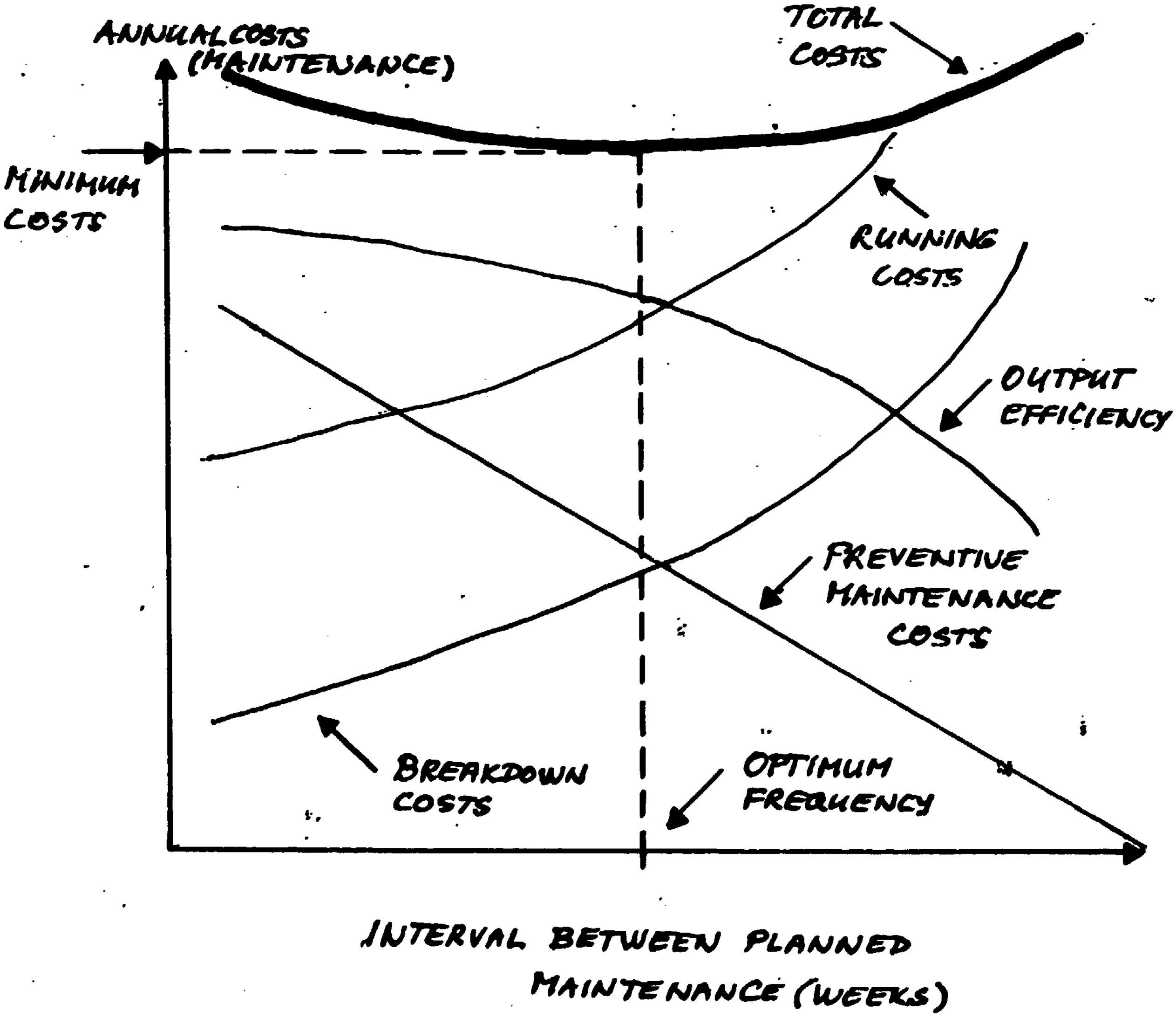


FIG. 2 ECONOMICS OF PLANNED MAINTENANCE

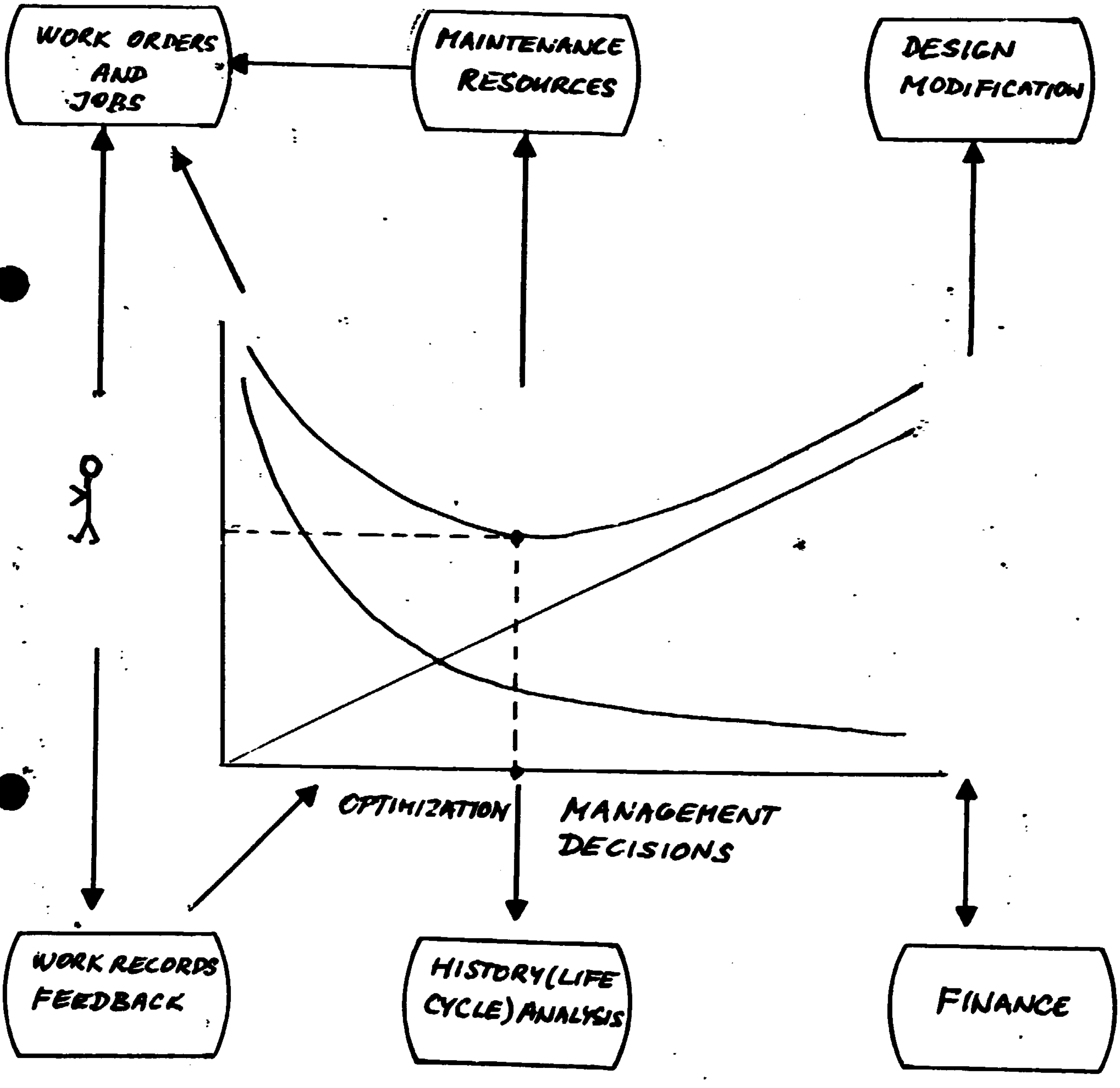


FIG. 4 OVERALL MAINTENANCE MANAGEMENT CYCLE

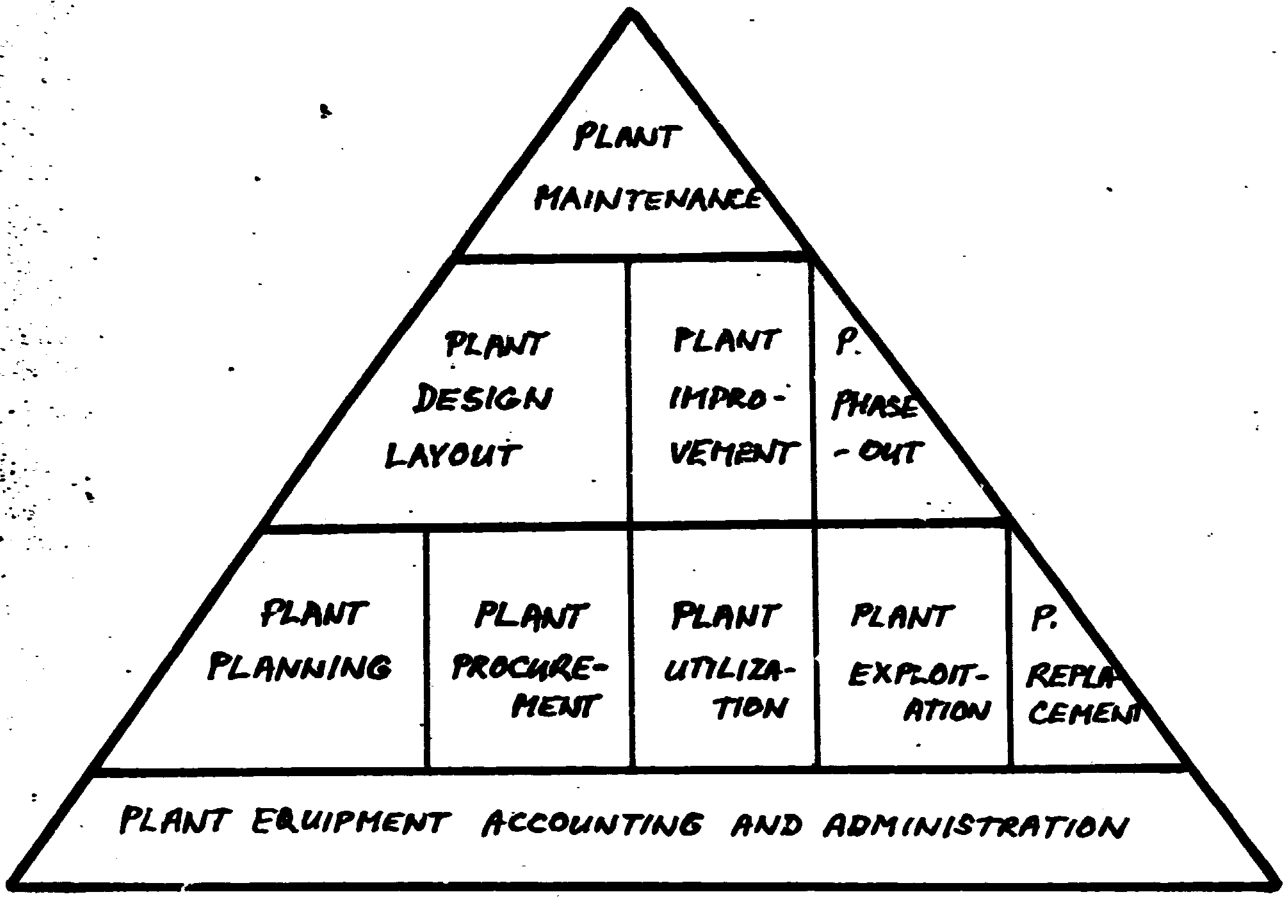


FIG. 5 LIFE CYCLE PLANT MANAGAMENT

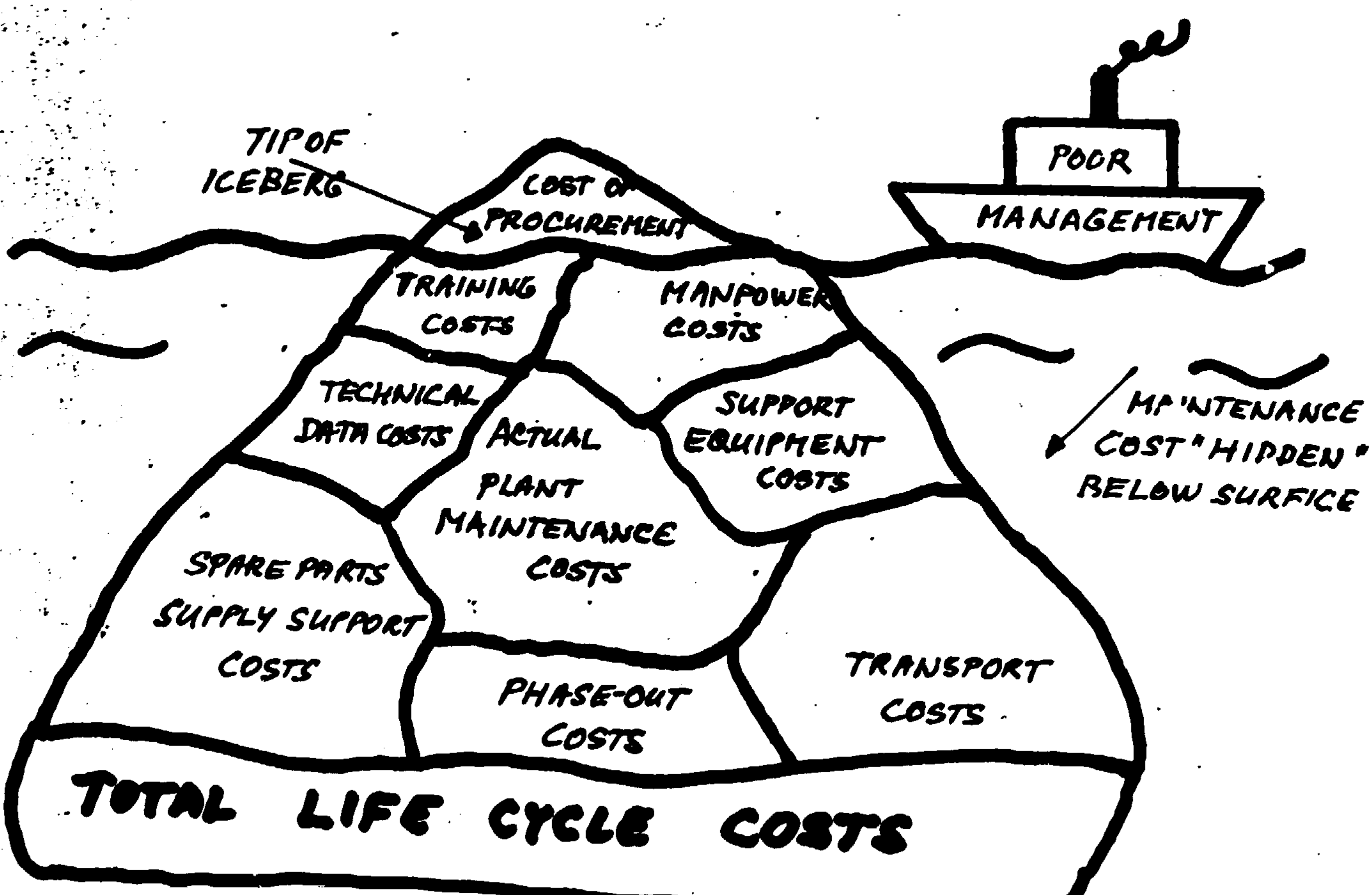


FIG. 6 PROCUREMENT V. TOTAL LIFE CYCLE COSTS

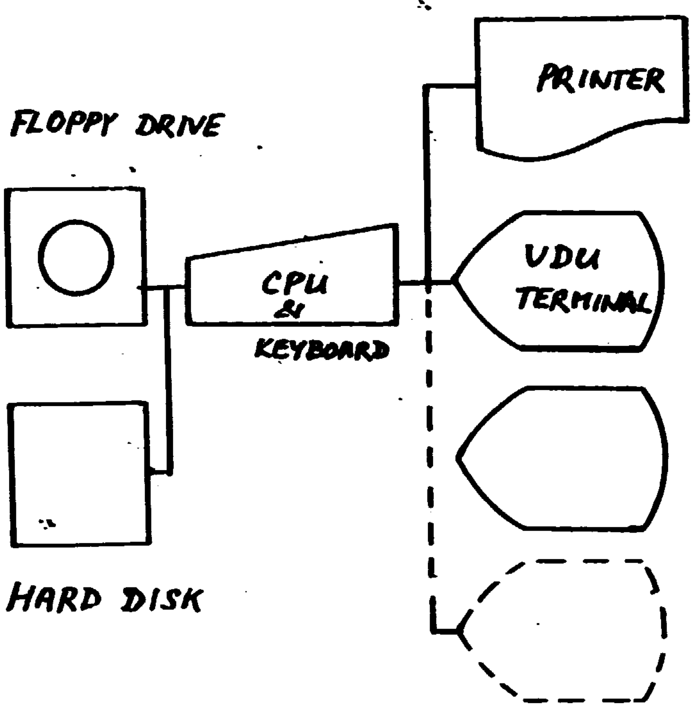


FIG. 7 MICROCOMPUTER CONFIGURATION

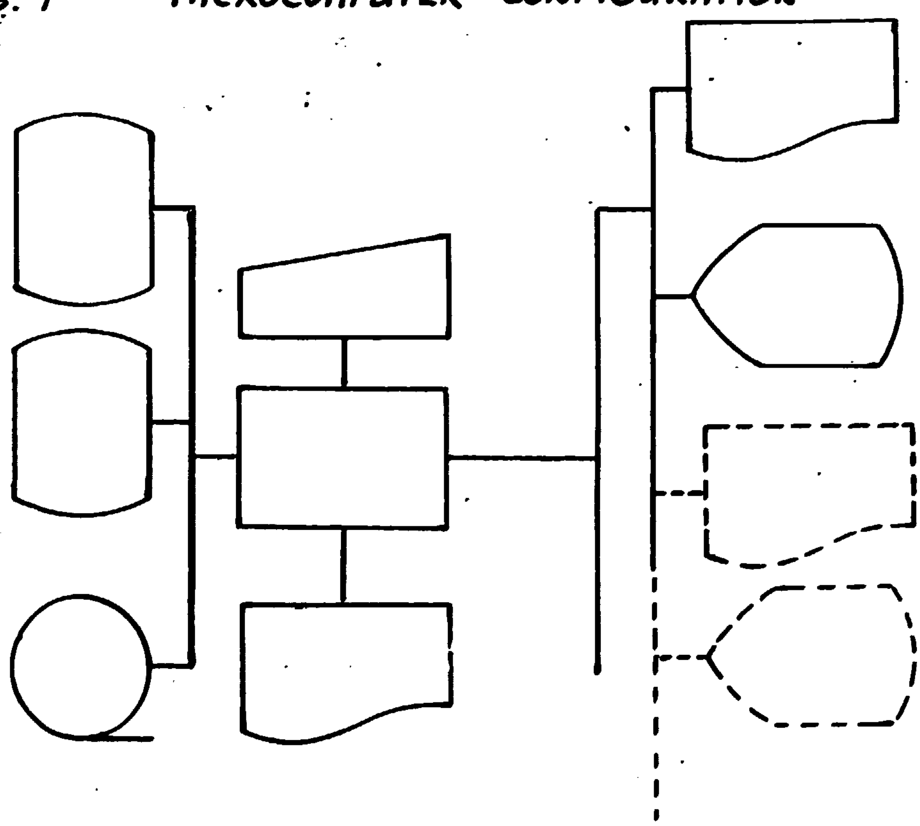


FIG. 8 MINICOMPUTER CONFIGURATION

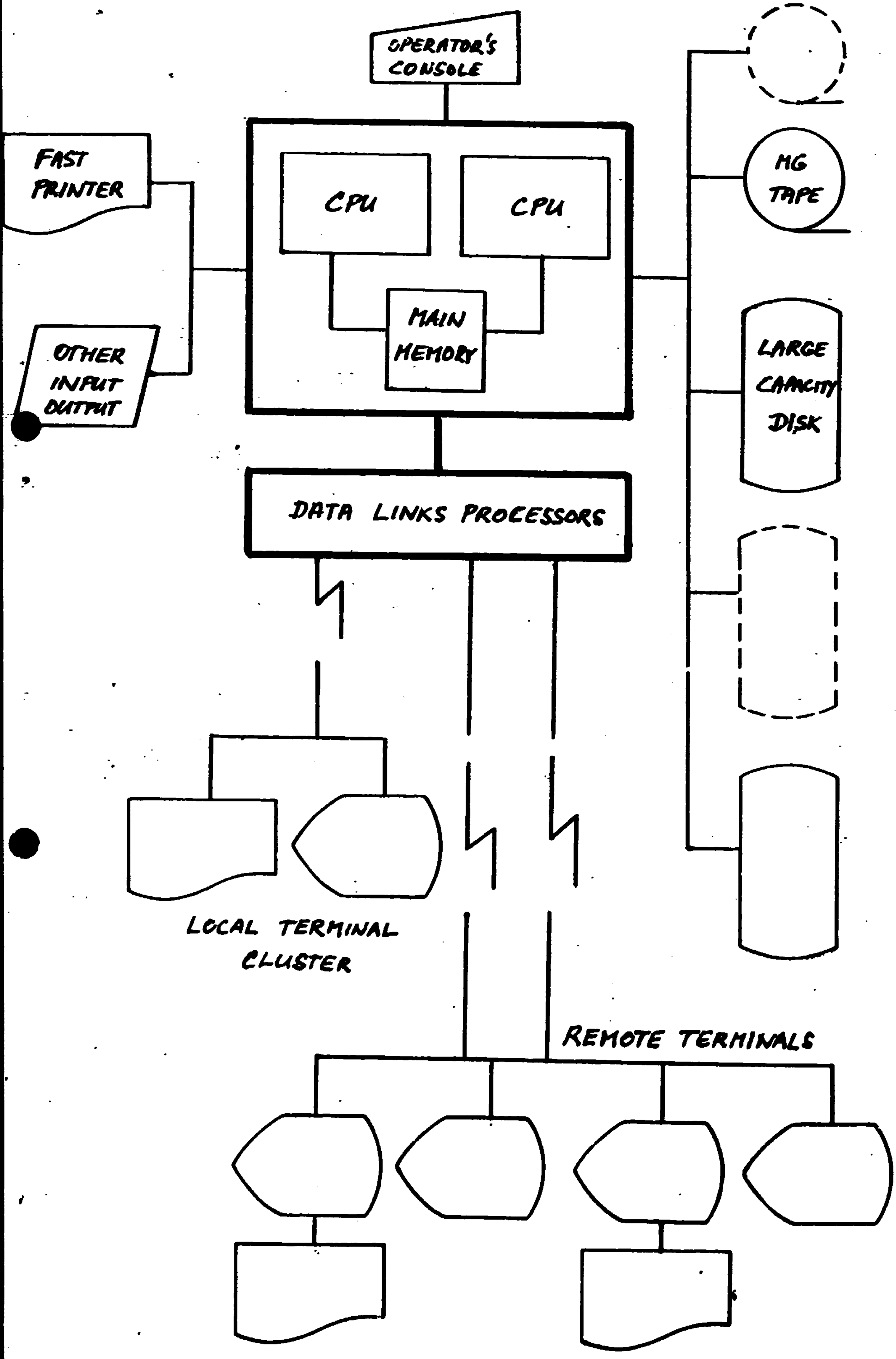
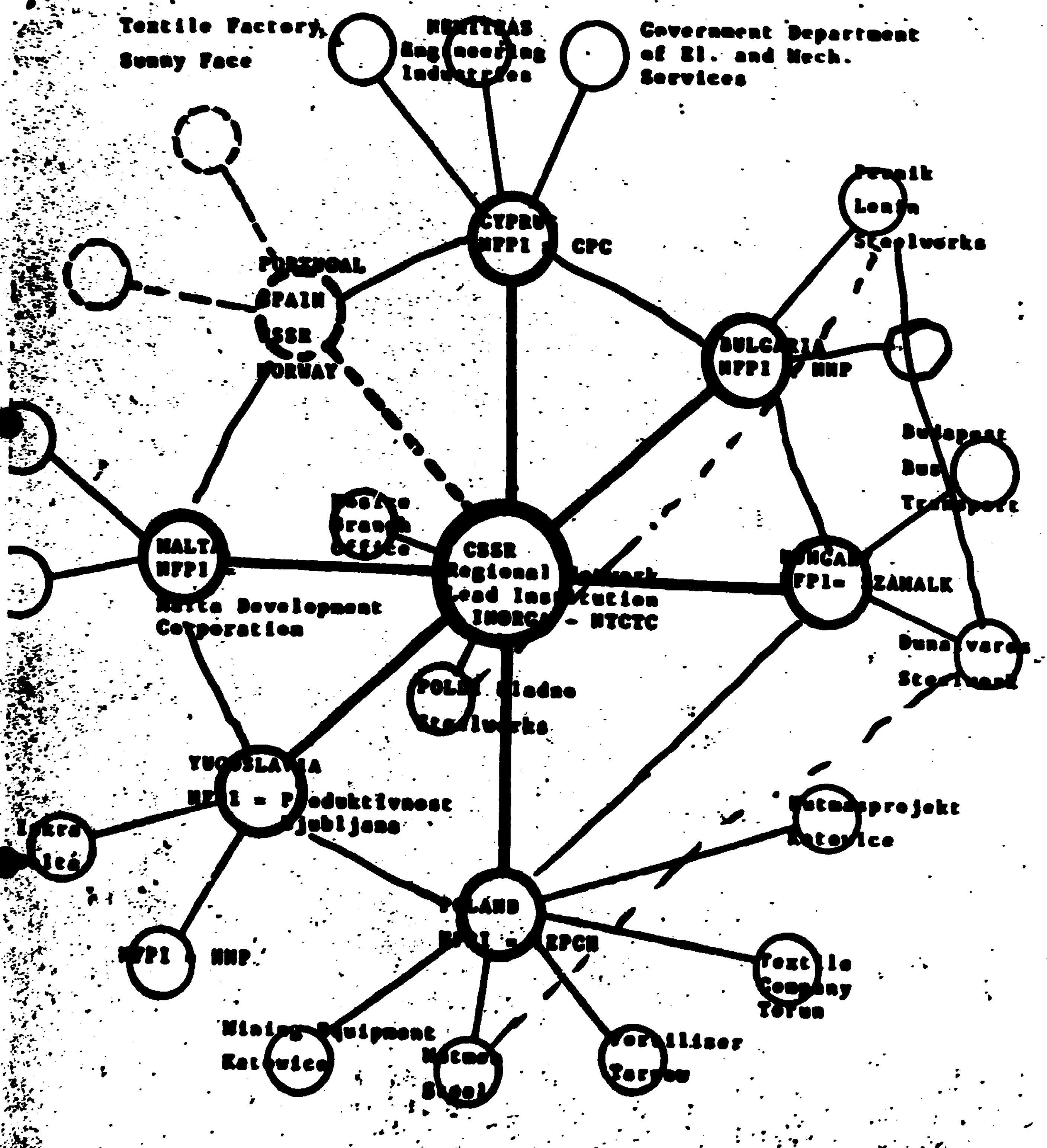


FIG. 9 MAIN-FRAME COMPUTER CONFIGURATION



PROJECT NETWORK NATIONAL FOCAL POINT INSTITUTION AND/OR
FIG.10 SUBNETWORK STRUCTURE