Microcomputers for Civil Engineering Consultancy
in Developing Countries.

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SUMMARY

The civil engineering industry generally regards new methods and technology with a high amount of scepticism, preferring to use traditional and trusted methods. During the 1980s competition for civil engineering consultancy work in the world has become fierce. Halcrow recognised the need to maintain and improve their competitive edge over other consultants. The use of new technology in the form of microcomputers was seen to be one method to maintain and improve their repuation in the world.

This thesis examines the role of microcomputers in civil engineering consultancy with particular reference to overseas projects. The involvement of civil engineers with computers, both past and present, has been investigated and a survey of the use of microcomputers by consultancies was carried out, the results are presented and analysed. A resume of the state-of-the-art of microcomputer technology was made.

Various case studies were carried out in order to examine the feasibility of using microcomputers on overseas projects. One case study involved the examination of two projects in Bangladesh and is used to illustrate the requirements and problems encountered in such situations. Two programming ap lications were undertaken, a dynamic programming model of a single site reservoir and the simulation of the Bangladesh gas grid system. A cost-benefit analysis of a water resources project using microcomputers in the Aguan Valley, Honduras was carried out.

Although the initial cost of microcomputers is often small, the overall costs can prove to be very high and are likely to exceed the costs of traditional computer methods. A planned approach for the use of microcomputers is essential in order to reap the expected benefits and recommendations for the implementation of such an approach are presented.

KEYWORDS

CIVIL ENGINEERING CONSULTANCY

MICROCOMPUTERS IN CIVIL ENGINEERING

MICROCOMPUTER SELECTION

OVERSEAS PROJECTS

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CHAPTER ONE <u>INTRODUCTION</u>

Sir William Halcrow and Partners initiated this research because of their awareness of the impact that microcomputers can have, particularly with regard to the operation of overseas offices. The work was funded by the Halcrow Water Company and is, therefore, principally concerned with all aspects of that company's operations. The Project was carried out in association with the Inter-Disciplinary Higher Degree (IHD) and Civil Engineering departments of the University of Aston.

In the early and mid seventies there was a Civil Engineering boom, particularly in the OPEC countries where new found wealth was eagerly spent in order to escape from Third World status. An abundance of work meant that competition between civil engineering consultants of the developed countries was small, since there was plenty of work for all. By 1978 the amount of work being tendered had been considerably reduced, and therefore, competition between consultants became fierce. In addition the under-developed countries had gained experience in engineering over the years and found themselves able to take on some of their own projects. Civil engineering consultancies, including Halcrow, developed a need to improve their competitive advantage in overseas work.

The main philosophy of the work in this thesis is based on the need to gain competitive advantage in overseas consultancy, especially in low labour cost countries which, with their increasing experience, are moving into an area traditionally covered by the consultant from developed countries. A large percentage, (76% in 1981), (Holbrooke,1982), of Halcrow consultancy work is in association with overseas projects, many of which are situated in Third World areas. Clients expect the use of the most modern technology and methodologies that are available, whilst keeping cost to a minimum.

The application of high technology on overseas projects manifests itself in two ways: the reduction in cost to the consultant in carrying out the specified task; and the reduction of cost to the client in terms of what is essentially produced. The benefits of the former can be readily appreciated by the client, particularly if passed on to him in the form of reduced costs. However, it is much more difficult to sell the idea of increasing payments to the consultant to reduce the overall costs of the final result. Therefore, if better technology is to be used in the form of microcomputers some way must be found to demonstrate the benefits. In addition to finding out how the microcomputer can assist the company's operations, the marketing of expertise must also be considered.

The microcomputer can be used for both technical and administrative chores by the project manager and staff. In certain projects, the microcomputer and the programs are expected to be left behind to be used as a follow up to the project by the local engineers. Frequently, due to the consultants responsibility to ensure the efficient transfer of technology to the client, local engineers will have to be trained to use the microcomputer during the project. This research is primarily directed at the factors involved in making a decision to use a microcomputer on an overseas project and the feasibility and applicability of the microcomputer on such projects.

There are many arguments for and against the use of the microcomputer within the civil engineering industry (and within Halcrow Water Company) but it must be realised that the civil engineering industry in the UK has been slow in the uptake of new technology and that British companies have to consider their foreign competitors who are far ahead in this field. It must also be remembered that often the clients in these developing countries are eager to receive new technology and the only way they can afford it is on projects where foreign aid is being used. Therefore they will seriously consider a tender which shows that such equipment will be used.

An interesting relationship to note is that of the funding agency, the consultant and the counterpart, (the client), and the role the microcomputer is playing in projects in developing countries. Many projects carried out in developing countries are funded by aid organisations. For example, the Bangladeshi economy is almost totally dependent on foreign aid. Agencies keep a large amount of control over major projects and often explicitly demand the use of computers on-site. With a limited budget this invariably means the use of microcomputers. Microcomputers do facilitate training and allow routines which are developed during the course of the project to be kept and run long after the consultant has left.

There is the ongoing argument that the microcomputer is too limited in its capacity, power and capabilities but it was felt that in many projects such a machine would suffice for a large percentage of the work carried out. In many developing countries the quantity and quality of data can be poor. Yet engineers, by sending data back to their head office computers still manage to design the most elaborate mathematical and simulation models, with little consideration of the data being used. A model and its output can only be as reliable and valid as the data being put into it. Therefore the use of the microcomputer on an overseas site with its limitations may merely serve to curb the development of too elaborate and complex models and puts the actual project in hand into perspective.

An investigation into the microcomputer technology 'state-of-the-art' is summarised in Chapter 2 of the thesis. Particular attention has been given to the hardware and software. The hardware refers to the physical components of the system as opposed to the software which is the programs. A review of the use of computers in the civil engineering industry is given in Chapter 3, including a recent survey of the consulting industry.

Chapters 4-7 constitute a study of the project using the systems analysis approach. Details of Sir William Halcrow and Partners are outlined in Chapter 4 along with the identification of the problems and objectives to be tackled by the research. Chapter 5 discusses the factors affecting the choice of a microcomputer system and the alternatives open to the consultant. Measures of effectivness will be established and a methodology for the choice of a microcomputer will be put forward. A case study of two overseas projects is presented in Chapter 6, and a cost-benefit analysis of an overseas project is carried out.

In order to practically examine the feasibility of using microcomputers for planning and screening models two computer applications have been written and tested. One involved the use of dynamic programming in the operation of a single reservoir scheme, the other was a simulation model of a gas grid system and its development. Both are presented in Chapter 7.

The trends in the microcomputer industry are investigated in Chapter 8 and forecasts are made as to the possible future state of the developing technology.

During the three years of this research Halcrow have increased their use of microcomputers. The developments during this time are presented and discussed in Chapter 9. Proposals for the future are also put forward.

The conclusions and recommendations to this thesis are given in Chapter 10.

CHAPTER TWO MICROCOMPUTERS

Over the past five years the microcomputer industry has advanced so rapidly that much of the literature is outdated within six to nine months of its being published. By the time conference proceedings reach the bookshelves the information they hold is often out of date. Much information on microcomputer technology is found in monthly journals and magazines and it is to these that the reader is referred. The current 'state-of-the-art' (1982) of microcomputer technology is reviewed in the following chapter.

2.1 Internal Structure of the Microcomputer

There are three basic components required to form a microcomputer system:

1) the microprocessor unit itself, and any required additional support chips.
2) the memory
3) the input/output (I/O) interface chips

An explanation of these components and how they function was given by Callcott (1982).

2.1.1 The microprocessor

The microprocessor by itself is not a computer but is the main component of the microcomputer. The microprocessor is a digital device using digital (binary) logic based on whether certain electronic circuits are on or off. The central processing unit (CPU) is contained within a single IC (integrated circuit), which is a complete microelectronic circuit containing thousands of transistors which have been placed upon a chip. The chip is made from a semiconductor material (silicon based) and can contain various components.

Two major types of chip technology exist , bipolar technology and MOS (metal-oxide semiconductor) technology. Bipolar devices are faster, but require large amounts of power and it is difficult to fit many devices onto one chip. Because MOS technology, although slower, requires less power more circuitry can be placed on one chip. With the emphasis of the 1970's being to cram more onto a single chip, MOS technology took the market lead. There are several types of MOS technology. They vary according to the actual materials used and the exact process of their manufacture. NMOS technology is the type used for most of the common microprocessors in microcomputers. CMOS technology, although slower than NMOS, requires very little power and is therefore becoming important in portable systems and systems requiring battery power.

The ability to place more circuitry upon a single chip of the same size was a consequence of improved etching and masking (processor manufacture) techniques. By reducing circuitry size it is now possible for memory and input/output interfaces all to be placed upon one chip. As these advances continue it is becoming progressively harder to distinguish between the microprocessor and the microcomputer, (Economist,1983a). The limit on the amount of circuitry placed upon a single chip is governed by several factors, one of the most crucial being the problem of heat dissipation. Some current research is aimed at improving chip technology by developing superlattices. Chips are normally made from wafers sliced from single crystals of silicon. Superlattices are composite structures built up from alternating layers of different compounds. (Economist, 1983b).

Companies developing chips used in the most common microcomputer systems are Zilog, Intel, National Semiconductor and Motorola. Some companies such as Hewlett Packard and Texas Instruments produce their own chips but high research and development costs often result in their equipment being of a higher price than their competitors. Table 2.1 compares the most common microprocessors used in microcomputers on the market today. A detailed description of some of these microprocessors is given by Huffman, (1980). Until 1983 the 8 bit microprocessor had been the most prevalent in the design of the microcomputer. However, the Intel 8088 processor became very prominent in 1981 and was used in many new microcomputer systems. The 8088 is an 8 bit microprocessor which features 16 bit addressing facilities and 16 bit internal architecture but still retains an 8 bit data bus and therefore can use 8 bit support chips. True 16 bit processors are gaining in importance but are far more expensive to implement than the 8/16 bit processors. In a review of the three major 16 bit microprocessors the Zilog Z8000, Intel 8086 and Motorola 68000, Heering (1980) concluded that the 68000 was the fastest and had the best architecture for compiler generated code; the Intel 8086 was the least sophisticated but had more support at that time.

The advantage of the 16 bit processor lies in its ability to directly access larger amounts of memory than the 8 bit processors. The introduction of the 16 bit wordlength has meant that many instructions of two words length are now one word, therefore making processing faster. The 16 bit processor allows a larger instruction set; it also fetches data twice as fast as any given clock rate for an 8 bit processor. Instruction sets of 16 bit microprocessors often provide facilities only previously found in minicomputers, e.g. floating point arithmetic.

A further advance in 1983 was the Intel iAPX432, a 32 bit microprocessor. The iAPX432 processor offered a massive increase in power and addressing facilities over 16 bit processors. The iAPX432 also provided several facilities not previously found on a processor

Microprocessor	No. of bits	Technology used	Length of data bus	Length of address bus	Addressable memory	Typical computer using chip
Intel 8080	8	NMOS	8	16	64K	Osborne 1
Intel 8088	8	NMOS	8	16	640K *	IBM PC
Intel 8086	16	NMOS	16	16	1 Mbyte	Apricot
Intel Transputer	32	CMOS	32	32	*	not implemented
Zilog Z80	8	NMOS	8	16	64K	North Star Horizon
Zilog Z8000	16	NMOS	16	24	8 Mbyte	Olivetti M21
MOS Technology 6502	8	NMOS	8	16	64K	Apple II
Motorola 68000	16	NMOS	16	23	8 Mbyte	Apple Mackintosh

* usually restricted by the operating system

Table 2.1 Comparrison of Microprocessors chip, such as in-built operating system functions (Spencer, 1983). In 1984, several 32 bit microprocessors were announced including the Inmos Transputer. The Transputer is expected to be used in the new fifth generation computers. As well as the increased addressing facilities and improved instruction set expected of 32 bit microprocessors, the Transputer also offers a massive increase in speed. It is claimed that the Transputer can run at 10 MIPS (10 million instructions per second), which is faster than many mainframe computers (Mateosian, 1984).

When choosing a microcomputer system it would be unusual for a civil engineer to have to base his choice solely upon the microprocessor. But speed and memory addressing capabilities are largely governed by the processor type and they may be important to a particular application or project.

2.1.2 Internal memory

The memory of the computer is needed to store program instructions which can only be supplied one at a time to the CPU to be executed. Two basic types of internal memory exist: RAM, (random access memory) and ROM, (read only memory). RAM, is a read/write memory, i.e. when the power is turned off whatever was stored in RAM is lost. ROM is also random access but its contents can only be read.

Traditionally internal memory was very expensive, but the introduction of chip technology has meant that memory can be produced at lower costs. The constraint on the amount of memory available on a microcomputer has recently been alleviated by the increased wordlength of the newer CPU's. An 8 bit microcomputer with a 16 bit address length may only address 64K words of memory at any one time since the computer works in binary and there are 2^{16} combinations =65,636 =64K words. Some microcomputers have the ability to switch in new areas of memory therefore effectively increasing the amount of addressable memory although only 64K is available at a time (bank switching). 16 bit microcomputers vary in the amount of memory they can access according to their architecture but most will access 1Megabyte words to 16 megabyte words of memory, (where 1 megabyte equals 1 million bytes).

2.1.3 Input/Output

In order to interact with the outside world a means of communication has to be set up to the CPU, (this is called a bus). Bus structures are used internally in the microprocessor unit (data, address and control bus). They are also used to overcome the problem of transfer of data from computer to peripheral equipment and vice versa. An interface is needed when peripherals cannot be directly plugged into the computer's system bus. Two of the most widely used interfaces are the RS232 and the IEEE 488 interfaces. Two of the most widely used bus standards are the S100 and the IBM PC cards.

Once an Input/Output (I/O) device has been connected to the computer a communication procedure must be established between that device and the processor. An important technique for controlling I/O devices is the interrupt mechanism; another is direct memory addressing (DMA). Input/output techniques are further discussed in Appendix A.

Bus and interface standards are unlikely to be major considerations when choosing a microcomputer system. However, it is preferable to choose standard systems, thereby allowing a wider choice of peripherals and simplifying the configuration of the system.

2.2 Mass Memory and Peripherals

2.2.1 Backing store

Backing store is essential for the storage of programs and data since a computer's fast memory is volatile. Fast memory is also limited in size on the microcomputer. It is, therefore, a precious commodity which should be used to its optimum. There are various forms of backing store. The main types used with microcomputers are cassette tapes, floppy discs, hard discs and laser discs. Cassettes are used to a lesser extent on business systems since they prove to be slow and information can only be stored sequentially. However, they are the cheapest form of backing store.

There has been an increasing trend in floppy disc drive technology for discs to become smaller. The 8" disc has been implemented in new microcomputer systems far less than the 5.25" disc in recent years and in 1983 the first commercial use of the 3.5" disc was announced. This increasing trend in smaller disc size is due to improvements in magnetic coating techniques. A more uniform coating allows a greater density of data to be stored (Tyler, 1983), and data access time is also improved due to the read heads on the drive having less mean distance to travel.

Winchester (hard) disc drives were fraught with reliability problems when they were first introduced to microcomputer systems. These problems have been reduced and, at the same time, the capacity of hard discs has been increasing (Britten, 1983). Some Winchester discs offer between 80 and 85 Mbyte storage capacity (8" disc). Winchester drives have been developing to the point where hard disc portability is becoming a realistic development in the next year (Sutton, 1983). Since hard disc systems are a sealed unit with a fixed capacity it is important to have back-up facilities. These are most often provided as floppy disc drives, although back-up media also exists in the form of streamer tape. Streamer tapes are 1/4" cartridge tapes which although slow, prove to be a reliable source of back-up and are particularly useful for archiving purposes. A recent development has been the exchangable hard disc, working on the same basis as those discs on mini and mainframe computers. The actual drive will be more expensive than the ordinary Winchester disc drive.

Laser discs are a relatively new form of storage media, they are write-only discs but provide a massive amount of storage (several gigabytes, where a gigabyte is 1000 megabytes). Laser discs are not magnetic devices like the floppy and hard discs. The discs are written on by a laser beam which etches the data into the discs, the power of the beam is reduced when reading data. Once the data has been written to disc it cannot be erased.

Bubble memory is a storage medium which has been pointed to as the storage device of the future. However it is still very costly compared to traditional storage devices and is rarely used.

2.2.2 Peripherals

A peripheral is the means by which the actual computer interacts with the outside world. The range of peripherals available today is wide but the capability of a specific peripheral must be carefully matched with the processor being used. The main types of peripheral are the visual display unit (VDU), the printer, the graph plotter and the digitiser; peripherals are very costly and in many cases exceed the cost of the microcomputer itself.

The VDU is an essential part of a microcomputer system, allowing the monitoring of input, output and program progress. It uses the same cathode ray tube (CRT) as television receivers, and works on similar principles. In many instances, the VDU is supplied with the microcomputer as an integral part. VDU technology has become more sophisticated and at the same time the cost of colour systems has been falling into the same range as monochrome systems. Although colour is rarely essential it often proves useful in providing a way to highlight information. The use of computer graphics can prove to be extremely valuable to the engineer by helping him interpret large amounts of data. CAD (computer aided drawing/design) packages are continually improving and may prove to be useful to the civil engineer. If CAD packages are to be used effectively sophisticated VDU's with high resolution will be required.

Character printers are devices which produce a permanent hard copy of computer output, and are one of the more slowly developing areas of microcomputer systems. They are often run by a microprocessor, which is an essential element in bidirectional printers (i.e. those that print in both directions). Printers can be classified into three broad categories : impact and non-impact printers, fully formed character and dot matrix character printers, and character at a time and line at a time printers. Borrell (1982) gave a breakdown of printers based on the classifications in Table 2.2. Line and page printers are usually associated with mini and mainframe computers, as are most of the non-impact printers. High reliability, speed and price/performance were considered to be major considerations when choosing a printer.

The serial, impact printer is the main type used with microcomputer systems. Dot matrix printers are adequate for draft work and program printouts, whereas daisy wheel quality is required for report writing and high quality output. Daisy wheel printers are often considerably slower than dot matrix printers. Multi-colour printers are available for microcomputers, and some printers have plotting facilities. Laser printers are now available for microcomputer systems, they print up to 8 times faster than daisy wheel printers but are considerably more expensive and little is known of their reliability.

TABLE 2.2 Classification of Printers.

CLASSIFICATION BY SPEED		
0 - 300 cps (serial printers)	300 - 400 lpm (line printers)	>4000 lpm (page printers)
CLASSIFICATION BY PRINTING METHOD		
Impact daisy wheel dot-matrix belt-band thimble, golf ball		Non-Impact thermal, electrostatic ink jet electro-typographic
CLASSIFICATION BY CHARACTER FORMATION		
	Fully formed Dot-matrix	

Graph plotters are designed to produce a permanent output of drawings, graphs, diagrams etc., i.e. lines and curves as opposed to characters. Data for graph plotting is held in computer memory or backing store and acquired by the plotter using plotting routines. Plotting commands are converted by the plotter-controller and communicated to the drive motors in the form of pen movements.

Digitisers provide a method of translating positional data from hand operated devices into digital data for input to the computer. They achieve greater accuracy than a light pen on a VDU, (which is also a form of digitising). Components usually consist of a cursor moved by hand and data entry controls, a plotting surface to sense the cursor position, a controller and interface electronics. An image digitiser can be viewed as a graph plotter in reverse, co-ordinates of points and lines being identified are subsequently given an image.

2.3 Microcomputer Technology

The number of microcomputers available today is well over 300. They vary in shape, size and configuration and choosing the 'right' one is a difficult task. Microcomputers can be classified into four basic types:

1) Small personal/home computers
2) Small 8 bit business computers
3) 16 bit computers
4) 32 bit computers

Personal/home computers are usually low memory systems using cassette backing storage and are considered inadequate for most business applications.

A general business 8 bit microcomputer system would typically consist of a computer, a monitor, a printer, dual floppy disc drives and at least 64K memory. The 8 bit microcomputer exhibits two disadvantages; their slow speed and the lack of addressable memory. During 1981 several 8/16 bit microcomputers were introduced. These 8/16 bit machines used the Intel 8088 chip but still used 8 bit support chips and 8 bit I/O facilities, therefore offering a larger amount of RAM associated with 16 bit processors whilst remaining at a considerably low price due to their ability to utilise 8 bit support chips.

An ever increasing number of 16 bit microcomputers have utilised the Motorola 68000 processor and some, to a lesser extent, the Zilog Z8000, these processors allow multiuser, multitasking systems to be implemented and approach the power associated with minicomputers.

32 bit systems are comparable to minicomputers, however there are few true 32 bit systems yet available and the amount of software available is quite limited.

Choosing a microcomputer system is a difficult task and many factors may influence the decision. When reviewing microcomputers most journals perform benchmark tests to measure average speed of certain processes. These benchmarks are usually a set of BASIC programs containing routines such as an addition, multiplication, division, trigometric and logarithmic functions. The routines are repeated in a loop many times to allow them to be timed accurately. However, such benchmarks give no indication of I/O speed, screen handling facilities or disc access speeds which can be just as important, (Pountain,1983).

Sales of the IBM PC (personal computer) microcomputer havemade a massive impact on the microcomputer market, clearly due to the reputation IBM has developed over its' many years in computing. The PC took between 18% and 25% of the market share in America in 1982, (Schofield,1983). This market lead has precipitated other component manufacturers and microcomputer manufacturers to direct their new equipment at the IBM market, usually by making them IBM compatible. Massive amounts of software havealso been developed for the IBM and many new microcomputers are being provided with the facility to read IBM discs. New technology did not move as fast in 1983 as it had been doing over the previous 2 years, the IBM machine had a snowball effect on the market even though the technology was far from revolutionary. The real 16 bit microcomputer systems are offering new technology and greater speed and power but have been slow breaking into the market.

Portable computers have increased in importance over the past two years. Lighter systems are being developed and screens are becoming smaller and flatter, thus portability is increasing. A review of portable computers was given by Wszola, (1983).

Initially microcomputers were typically dedicated to a single user system , this can lead to decentralisation within a company and causes software problems with duplication of effort and poor communication. Recent emphasis in microcomputer technology has been upon the development of communications and networking facilities. The term 'local area networks' is liberally used for various types of communications applications. Networks allow a user to preserve his independent use of the microcomputer but allow him to share information with others. Networking can be identified from multi-user systems using such time sharing operating systems as MP/M and UNIX. Networking essentially allows a user to share information with other users but still operate his own dedicated system. Device sharing, e.g sharing printers or disc drives, is not true networking. e. A local area network (LAN), is a communications device of some sort allowing information transfer over a geographical area of about 6 miles. Each node on the network has the ability to communicate with any other. Messages are sent via communication media to the intended respondent.

Various types of network standard have emerged, the two major types are Ethernet and the Cambridge Ring. Ethernet works on the basis that once one message has begun to be sent another mesage transmitted at the same time would cause a 'collision'. The transmitting station would then sense the collision and a stop transmiting. Once a collision has occured each other station on the network is given a random time delay (time lag) and cannot start to transmit until their time delay is over. This ensures that several stations do not attempt to re-transmit at the exact same time . The Cambridge ring has its stations in a closed loop, messages are transmitted in one direction, being amplified and repeated as they pass through a node. The system is based on a 'token' strategy. That is a token circulates on the ring and when a station wants to transmit it replaces the token with its message. At the end of the message the token is replaced back onto the ring,. (Saal,1981). The Cambridge ring has the disadvantage that if one node fails the others cannot continue without it. As databases become larger and organisations become more dependent upon the microcomputer, communications will become more important and networking systems will increase in number.

2.4 Software

2.4.1 Operating systems

An operating system is a program, or suite of programs which act as an interface between the user and the actual hardware of the computer. An operating system allows the user to employ the computer hardware without having to understand the actual details of its operation. The operating system deals with all requests for service, (from the user or from the users programs). It handles inputs, outputs, interrupt processing and other supervisory functions. The operating system also provides a suite of user programs, such as the editor, the assembler, and the loader.

Only a few years ago the operating systems being implemented on microcomputers were very primitive. Today, users are demanding operating systems as sophisticated as those found on minicomputers, (Hemenway, 1981). Several types of operating system exist for microcomputers, which can be broadly categorised as being single user or multi-user. In a single user system only one person may access the operating system at a time, whereas in a multi-user system more than one person may do so and the system determines how the resources are shared. Operating systems are also classified according to how many processes may be run at one time, a process being a collection of procedures, functions and data which perform an independant task concurrently with the execution of other processes. Most microcomputer operating systems allow only one program to be processed at once.

A distinct type of operating system has evolved for the microcomputer: the disc operating system (DOS). The DOS is designed to support a user to prepare, test and run a program on a microcomputer with hard or floppy discs. Services provided by the DOS may be accessed by the user at a terminal or from within a program. The two most basic requirements, which are fundamental to a DOS are: the device and file management. Device management software handles the transfer of data to and from the peripheral devices, while the file management software must maintain correspondence between the symbolic filename and the file's physical location. Many file management system schemes exist. Some organise the disc space as a sequential series of records and so to find a record the file has to be sequentially searched. A direct (or random) access file, however, is organised such that an index is maintained on disc which consists of a series of pointers to the records of the file, so by using the index, specific records can be accessed.

In order to give the reader an account of the organisation of an operating system, the basic methods employed by CP/M (control program and monitor) and UNIX operating systems are discussed and reviewed in Appendix B. CP/M, is the most successful 8 bit microcomputer operating system. UNIX, originally a minicomputer operating system, has recently been adapted for 16 bit microcomputers. Phillips (1983) argued that although CP/M was the standard 8 bit operating system the translation to a 16 bit environment in the form of CP/M 86 had failed. He went on to review other 16 bit operating systems for the microcomputer and what they offer.

Several 16 bit microcomputers advertise that they have UNIX implemented on their machines. However, it was initially reported that implementation problems did exist, and this resulted in some implementations which are very different to the original UNIX. However, UNIX and UNIX-like operating systems should be recognised as a powerful alternative to CP/M's suppremacy. It has been recently announced that IBM have decided to support UNIX for the IBM PC, (PC/IX), this would probably have a large effect on the use of UNIX since other companies are bound to follow suit in order to emulate the IBM system. Rundle (1983), gave a full review of UNIX and how it is used.

2.4.2 Programming languages

Computer languages can be categorised into three types: machine code, assembly languages, and high level languages. Machine code is the actual instruction set of the computer. All such instructions have to be written with addresses and labels to the actual internal registers being used. Assembly language is a system which allows a symbolic representation of instructions,labels and addresses. This makes programming slightly easier, but a program known as the assembler is required to decode the instructions into machine code. High level languages are basically machine independent languages which require complicated programs to decode them, known as compilers and interpreters. High level languages have simplified the art of programming in the past 20 to 25 years, enabling people other than computer scientists to make full use of available computer facilities.

A high level language (HLL) allows the program to be written in a formal, structural way. The main advantage of HLLs is the ease of programming. Programmers can produce one line of HLL code as quickly as one line of assembly code but the programmers need not know how the computer is working. HLL execution speed however, is far slower than assembler or machine code, because of the longer translation phase. One line of an HLL is usually equivalent to several lines of assembler code.

There are many commercially available programming languages which may be implemented on microcomputers. In engineering applications the two most commonly used languages are BASIC and FORTRAN. BASIC is the most widely used language on the microcomputer. However, with increased sophistication of hardware systems, software is also expected to develop and high level languages such as PROLOG and LISP are becoming increasingly important. PROLOG is an HLL designed for the development of expert systems (a suite of programs which emulate an experts knowledge). Such improved HLL's are essential for the development of fifth generation systems and artificial intelligence.

2.4.3 Software packages

There are three basic types of software package: those which have been developed 'in-house', 'off-the-shelf' packages, and 'made-to-measure' packages. In-house and made-to-measure are similar except that in-house packages are developed by the user for a specific problem, whereas made-to-measure packages are developed for the user by a software house or a contract programmer.

There are many off-the-shelf application packages available, to meet widely different needs. Many of the packages for microcomputers are concerned with business applications, such as accounting packages, database management systems, and word processing packages. There are far fewer technical and engineering packages available. The main disadvantage of software packages is that they are often too general in that they may do far more than the user requires, or not enough. They may also produce far more output than is necessary or too little. Most of these packages are also copyrighted, and therefore cannot be modified to suit individual users.

Database management systems and the concept of the database has gathered considerable impetus over the past couple of years. The basic concept of a database is to store a piece of data only once and to route all subsequent requests for that data to it. It is thus a unique piece of data which can be related to the rest of the database in some way. The term 'database management system' on the microcomputer has been coined for differing systems and for differing purposes. The packages available vary considerably in their ability to store, retrieve and manipulate data. A review of the database systems available for the microcomputer was produced by Heintz (1983). Various 'electronic spreadsheet' packages are available on the market, all of which portray similar functions and facilities. Spreadsheet packages are proving increasingly useful as calculators for engineers and can used for quite complex tabular procedures.

2.5 Summary

The microcomputer market is at a stepping stone in its development. The 8 bit microcomputer has been the most important to date but the recent introduction of 8/16 bit and 16 bit machines are setting a new trend. New systems are threatening the power of minicomputers at far less cost. When choosing a system for a particular project there are many factors to take into account. The following chapters will examine these factors and determine the best role for a microcomputer in civil engineering consultancy with emphasis upon the overseas project.

CHAPTER THREE COMPUTERS IN CIVIL ENGINEERING - A REVIEW

3.1 General Use of Computers in Civil Engineering

The early history of the computer in civil engineering is not well documented. Only recently have journals begun to include articles on computing in the industry. Although the computer has been acknowledged throughout the past twenty years, for instance in the use of dynamic programming applications, there are very few papers on the functions of the computer in general civil engineering practice.

By the late 1950s the computer was having a vast impact on many areas of research. Two main trends were emerging and were of importance to the civil engineering industry. Firstly, powerful new analysis capabilities were presented and new techniques developed, e.g. the finite element method. Such techniques made use of the computers ability to handle large numbers of discrete equations and required a new more general approach to modelling in civil engineering. Secondly, the need to analyse large amounts of data could be met (Fenves, 1982).

Fenves noted the drop in relative cost of hardware and increase in hardware capabilities over the years whereas software costs had remained fairly constant. He warned of the many intangible costs to be taken into account when considering a computer system. He identified the many assets of the computer, but also noted their disadvantages and the shortcomings that can arise from the nature of the civil engineering industry. The latter include the duplication of efforts and the project orientation of the profession which is often reflected in the way in which computer aids are developed. Civil engineering programs are often very specific to a particular project. Fenves identified five major expectations from the use of computers by civil engineers:-

1) reduction of costs

2) more accurate modelling

3) ability to consider more alternatives

4) closer integration of civil engineering works

5) improved office practices.

The development of computing in the civil engineering industry in America was particularly reviewed, and the author assessed the microcomputers role for the future.

Schiffman and Krueger (1972) reviewed computer hardware and software used in civil engineering. The authors identified a lack of use at that time. Significantly the authors identified the lack of portability and adaptability of programs as the major reason for this low usage. More emphasis on software development was seen to be needed, and it was recommended that standards had to be identified and established. Shiffman and Krueger identified problems of language differences, dialects, software environments, documentation and maintenance. The authors also recognised the significance of the Genesys project being carried out in Britain, (a concentrated effort to apply computer based standards and processes to civil engineering).

Genesys (GENeral Engineering SYStem) was set up in 1967 in Britain to develop software for the construction industry. The system was an enterprising idea attempting to make the computer system transparent to the engineer by allowing him to input fairly simple directives to carry out a job, (Alcock and Shearing,1970).

Bland (1975) examined the interactions between computers and engineers, and stated that in order to use the computer effectively a clear set of objectives should have been previously established. The author put forward four basic objectives as minimum essentials :

a) to reduce the overall cost of doing business

b) to minimise cost to clients

c) to compress design and construction schedules

d) to extend the capability of the professional panel

Bland went on to define several specific criteria with which computer activities could be gauged. These were split into two areas: program development and program applications. These criteria were to act as a useful checklist during computer use, and should prove useful to a company which intends setting up procedures to monitor both use and benefits of the computer. Bland emphasised that although the computer is useful it is an expensive tool and consequently proper procedures should be adopted and actively supported at all levels of management if the expected benefits are to be reaped.

On considering the acquisition of a computer system, Lipetz (1978) noted that for most consulting firms the purchase of a computer was one of the largest and most significant investments they would ever make. The computer not only makes a large impact directly in the initial and continuing monetary outlays but also affects the way in which the company will carry out its future business procedures. More important Lipetz indicated that once a company has made that investment and had acquired a computer they would find it virtually impossible to revert and dispose of the machine.

In an overview of computers in civil engineering Crozier-Brown (1978), warned that the law of 'the survival of the fittest' still existed and that if engineers did not act upon the new technology that law would take its toll. Again the lack of software was identified as the major problem area because although hardware had advanced the amount and quality of engineering software available made those advances virtually worthless with effective software being expensive and difficult to locate. When examining computer use, he stated that:

"-------the computer, while offering many economies should not be looked upon as a cost saving device, but rather a tool that when used properly can save time, assure greater accuracy and enhance the total capabilities of the engineer".

Crozier-Brown also emphasised the need for complete support from management if the computer was to be a success. He stated that although the civil engineer does not need to be a computer expert to make use of computer facilities, special consideration should be placed upon computer education and training. In conclusion, he stated that to survive in todays world competitiveness a company would have to invest in some form of computerisation.

The problem of poor software was examined by Fenves and Schiffman (1979), who suggested that quality assurance of software could be tackled by considering size categorisation in the development of programs. They suggested that programs could be developed by the engineers themselves, but large programs should be developed by professional computer programmers. However, no exact idea of program size distinction was given.

Bowles (1981) investigated the reliability of computer programs and noted several basic areas where errors could occur. These included inadequate program documentation, lack of internal program testing and expansion of already existing programs. These errors would equally occur in in-house software, or software bought-in. Several methods were suggested in order that a company could put its software in order and boost the confidence of engineers. However, familiarity of the software was pinpointed as the best policy, whilst documentation of programs was regarded as extremely important.

The problem of software reliability was highlighted recently when design failures were observed after a local authority had built a multi-storey car park based on a design using a computer program. The waffle slab design was improperly set out and a computer fault was subsequently blamed, (Middelboe, 1984). This design failure was significant since it appeared to be the first time a computer fault had been openly identified as the cause and shows that the procedures when using a computer for design should be carefully studied. It also highlights the fact that highly qualified engineers are still required to examine computer results and they should be responsible for the final results.

Taffs (1981) in a review of the use of computers by British consulting engineers, reported that American consultants had taken up the challenge of the computer far faster. He implied that the major causes were higher salaries for engineers using computers and cheaper hardware. Many of the major British Engineering Institutions did not actively promote the use of computers until the late 1960's. By 1970 only a dozen or so of the larger civil engineering consultancies had IBM, ICL, or DEC computer systems. One major factor causing this complacency was the lack of reliable information on the benefits of computer use. Taffs also pointed out that few of the organisations monitored their activities, therefore when computers were introduced there was little basis for comparison. Taffs claimed that within his own company he had shown that computers had not given the benefits that were continually being claimed. He stated that "Computers are therefore not the key issue in improving competitiveness". Efficiency, Taffs claimed, is the major problem area which in turn involves the human factor, attitude to work and the computer.

In conclusion, Taffs predicted that the number of small computers in civil engineering in Britain would rapidly expand but they would not be as beneficial as their owners would be expecting. However, since costs of microcomputers are small they would be largely lost in the overheads.

3.2 Microcomputers in Civil Engineering

Since the advent of the microcomputer in civil engineering more literature has been produced in Britain than in previous years, with conferences and technical data being made available. The function of the microcomputer in civil engineering consultancy in Britain has been publicised far more than in previous years. Unfortunately many of the papers presented in this area are based on personal thoughts and feelings rather than solid research.

Two reasons have been identified during this research for the poor quality of much of the literature :

i) the use of microcomputers is still in its infancy in civil engineering and little research has been performed as to their benefits.

ii) Many authors write of their own experiences, based solely on the companies they work for. Because of the competitiveness in the civil engineering industry at this time their words have to be guarded. Further, it seems that many sales agents have begun to enter the world of 'academia' by producing papers in the hope that they will gain respectability and sell more equipment.

A significant piece of work by Johnson (1981) provided guidelines for engineers purchasing a microcomputer system. The professional microcomputer he was considering was probably rather more powerful than those being considered by most civil engineering companies in Britain at that time. He warned that although small computers have immense potential, they might also prove to be very costly if implementation was not carefuly planned and monitored. The types of applications best suited to the microcomputer were identified. A set of criteria to justify microcomputer acquisition, evaluate microcomputers, select microcomputers, purchase microcomputers and finally monitor the system were provided.

Johnson claimed that the BASIC language was the most popular on the microcomputer with PASCAL second and FORTRAN third (on 8 bit computers). CP/M was the most popular operating system. On 16 bit machines FORTRAN was the most popular language, with compiled BASIC second and UNIX the most popular operating system.

In proposing a methodology for choosing a microcomputer Lustman et al (1978) put forward three initial conditions:-

1) a computer department is needed
2) the choice is made on tenders
3) the whole system is proposed by one supplier

These conditions are interesting since a microcomputer is not defined by the authors and probably refers to a minicomputer of today. These conditions would rarely be adhered to now, particularly for a microcomputer. Lustman et al's paper shows the speed at which the computer industry has moved and the changes that have rapidly occurred. However, some of their advice has stood the test of time. Firstly they state that a company should not be looking for the best computer in the world, but the computer that will best fulfil their requirements. Those requirements must be identified by the buyer not the salesman. Secondly, system capabilities should be thoroughly examined and salesmen should not be taken as experts. Finally, reference manuals must be examined and not the colour brochures.

In a look at recent and future developments in the role of microcomputers in the design office, Taffs (1983) claimed that the microcomputer had been of little use to the profession. He blamed this failure on the lack of good technical software and the structure of the civil engineering industry. Taffs believed that the 8 bit microcomputer was still the best buy, but that it could only be sucessfully used for financial and administrative applications. He claimed that design software was of a poor quality and often required extra expenditure in terms of support and maintenance.

3.3 Applications on the Microcomputer

Availability of software is a major problem in civil engineering. Some aspects of civil engineering have been heavily exploited, eg. structural analysis, usually because the programming is easy and there is a large commercial demand, whereas, techniques such as finite element methods are difficult to program effectively on the microcomputer due to its limited capacity and speed and the high degree of processor utilisation. Other engineering applications such as some aspects of water resources only have a limited demand and therefore are not commercially viable.

Brentano (1978), whilst examining computers in the civil engineering office, discussed several applications being used day to day in engineering companies. He noted that structural analysis and design were the best known civil engineering applications with an estimated 1500 packages available in America. He claimed that in structural analysis productivity had been increased by the use of the microcomputer. Project control and management were other areas of engineering just as suitable for computerisation. Techniques such as the CPM (critical path method), (a project management technique), were ideally suited to the microcomputer, as were construction management and cost estimating techniques. An area where labour intensive and tedious work could be eliminated was that of surveying, mapping and drafting. Further applications well suited to the microcomputer included transportation and planning and hydrologic engineering. Brentano emphasised that although the computer could clearly reduce the physical time spent on a problem or project it would not replace or reduce the need for responsible, experienced engineers. The computer should be regarded purely as one of the many tools available to the engineer.

Males (1982) looked at computer applications in water resources planning. He identified a lack of software, which he attributed to many water resource problems being situation specific, unlike other areas such as structural analysis where programs can be used repeatedly. Water resource problems are often site dependent and have probablistic characteristics. They may include environmental, social and political factors. Males went on to identify several American national water resource planning programs.

An important area of computing in civil engineering is known as CAD, (computer aided drafting/design). This area is predomininatly involved with drawing and therefore computer graphics are required. Computer graphics is an area of computing which requires large amounts of memory and the price of software is high. Garrett (1982) gave a review of CAD, mainly used in America. He produced a series of five year cash flow projections and made a comparison of expenses, with and without a CAD system. Although the results showed that it was favourable to employ a CAD system with an initial total expense of approximately $421,000 it is perhaps not surprising that few engineering companies have done so. Some simpler systems are available on the market, (McCool, 1980) particularly on the Commodore PET (32K). These systems lacked decent graphics facilities, but could be used sucessfully for designs such as framework analysis, beams, slabs etc. However, the general opinion of large consultants (Taffs, 1981) is that the microcomputer had not developed enough to be used for CAD applications.

Neale and Boland (1980) developed a program to design scaffold falseworks on a Hewlett Packard 9845A microcomputer. Based on the draft British Standard code of practice for falseworks the program was used to produce the design, the cost estimation and the scheduling for a project in ten hours (2 hours of computer time and 8 hours studying results). It was estimated that the equivalent work would have taken four man-days by traditional methods.

Attitudes and opinions towards the use of the microcomputer in civil engineering varies from author to author. Some claim that benefits of its use are large, whilst others state that it is not producing those benefits. It was difficult to assess how much use was being made of the microcomputer in British civil engineering consultancies from the literature. There was also a lack of literature on the use of microcomputers in the field and on overseas projects. It was therefore decided to carry out a survey, in order to determine the impact microcomputers were having.

3.4 Microcomputer Survey of Engineering Consultants

The survey was carried out in an attempt to indicate whether or not microcomputers were having any effect on British civil engineering consultancies, since the literature reviewed gave little indication of their impact. It often takes up to twelve months to publish proceedings of conferences and any relevant literature was out of date and bore little relevance to the microcomputer state of the art during the period of the research. By organising a survey of microcomputers within civil engineering consultancies it was felt that a 'snapshot' of the impact of microcomputer technology on civil engineering at that time would be obtained. It is important to note the impact and use of microcomputers on consultants in this country before going on to look at how they should use them on overseas projects, the former having large consequences on the success of the latter.

The survey questionnaire was designed to identify whether and to what extent engineering consultants were using the technology available to them. Its design was to be as simple as possible since it was impossible to gauge the ability of the respondent. However, it was impossible to remove all of the jargon associated with the microcomputer industry. The questionnaire was fitted on to both sides of one A4 sheet of paper. In order to reduce the amount of paperwork the respondent received and to encourage a large response. All questions on the form were of the multiple choice type. Thus making data analysis easy and eliminating problems of analysing 'points of view'. The last question allowed the respondent to make his own comments.

A pilot study was carried out by giving the questionnaire to a selection of supervisors, technicians and students at Aston University to test its clarity. The pilot study was also aimed at evaluating the reliability of the questionnaire, since the answers received were already known and could be checked.

The sample for the survey was taken from the total population of civil engineering consultants who were members of the Association of Consulting Engineers,(ACE). The total population was taken from the "Consulting Engineers Who's Who Book 1982/3". One section lists all companies which practise as consulting civil engineers. The total population consisted of 329 companies. Due to the constraints of time and cost a sample size of 100 was adopted. These 100 companies were chosen randomly, with nothing being known about any of them prior to the survey other than that they were members of ACE. The questionnaire was addressed to the senior partners of the companies involved, in the hope that sufficient interest would be generated for them to complete the form or have the form completed by some suitable employee. The respondent was offered total anonymity if they wished, but were offered a resulting fact-sheet if they did supply their name and address. All questionnaires contained a stamped envelope for return.

3.4.1 Survey results

A response of 87% was received, this is unusually high for a postal survey of this type and was seen to reflect the interest in microcomputers in civil engineering consultancy. Ideally it would have been useful to try to follow up the missing 13% that had failed to answer the questionaire in order to achieve a 100% response, but due to some companies remaining anonymous it was not feasible to identify those who had not responded within the timeframe of this study.

Respondents were asked to indicate the size of their company by the number of personnel they employed. There were no replies from any companies with more than 2500 employees. Figure 3.1 shows the size distribution of responding companies, most having between 0 and 100 personnel. Over 80% of the respondents had 500 employees or less.

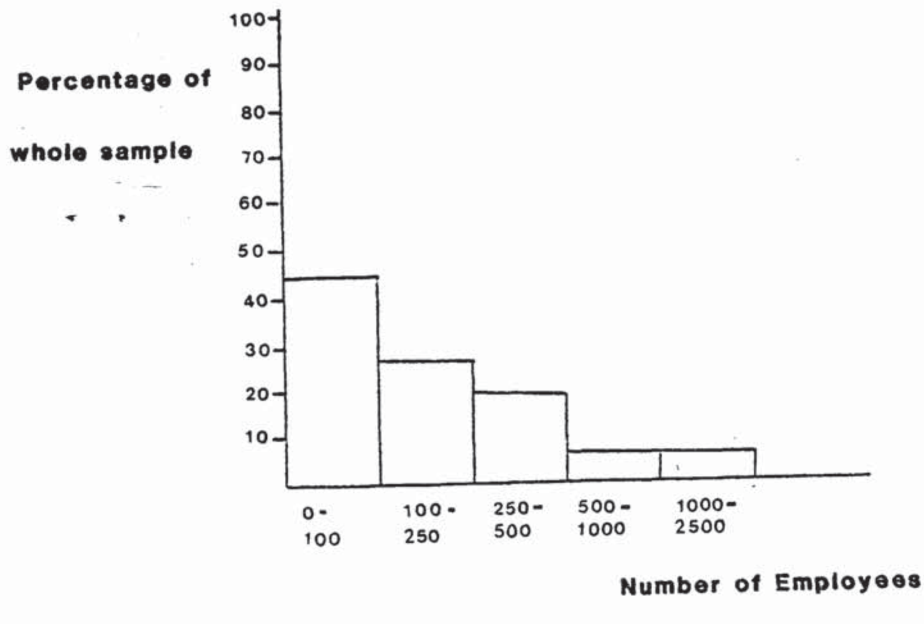


FIGURE 3.1 Size Distribution of Responding Companies.

Of the 87% of companies which did reply, 18% did not use microcomputers, and surprisingly 2% of the respondents did not use computers of any type. Figure 3.2 gives a breakdown of the percentage of companies, classified by number of employees, using microcomputers. It is difficult to state whether the sample is truly representative by size because the number of employees in each company is not given in the Consulting Engineers Who's Who.

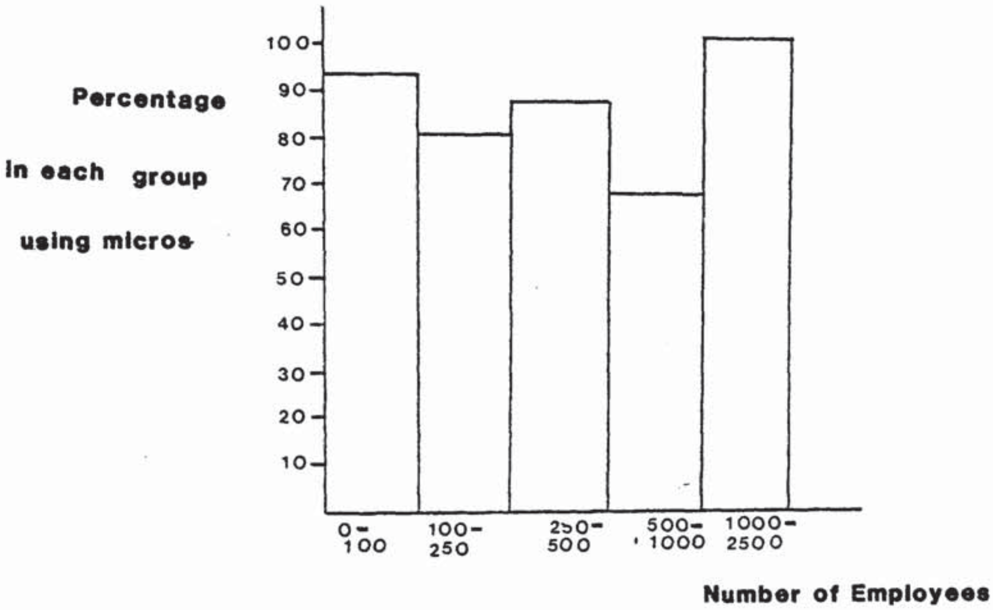


FIGURE 3.2 A Breakdown of the Total Sample Using Microcomputers.

Only one of the respondents used more than 60 microcomputers, the majority of companies had between 5 and 20. The number of microcomputers increased with the size of the company as expected. Table 3.1 indicates that the smaller companies tended to have more microcomputers per personnel. It might have been pertinent to enquire whether the company had standardised to one particular computer manufacturer or had several different types at this point in the questionnaire.

TABLE 3.1 Number of Microcomputers to Company Size.

No. of Microcomputers	1-5	5-20	20-40	40-60	>60
No. of Companies	68	15	3	0	1

Next, the questionnaire asked whether the microcomputers were all situated on one site, as opposed to being distributed throughout their regional offices. The question was intended to discover whether the introduction of microcomputers was concentrated in some small area of the company or whether it had more wide reaching effects. It would seem from the response that microcomputers were not being used merely by one faction within a company, but were being used on a broader basis.

In order to investigate the types of application for which microcomputers were being used five categories were given on the questionnaire:-

1) Accounting and Finance.
2) Management Information Systems.
3) Word Processing.
4) Mathematical Modelling.
5) General Technical/Engineering Problems.

The respondents were asked to indicate for which of these applications microcomputers were being implemented. Applications tended to vary greatly from company to company. This was seen as a difference in approach by individual companies and in the identification of the engineering applications on the microcomputer. The most common application was the use of the microcomputer to solve technical and engineering problems, all but one company gave this answer. Figure 3.3 assesses the use of microcomputers in civil engineering consultancy work. Only 11% of the respondents with micros use them in all 5 categories, but 62% use the microcomputer for 3 or more of the applications.

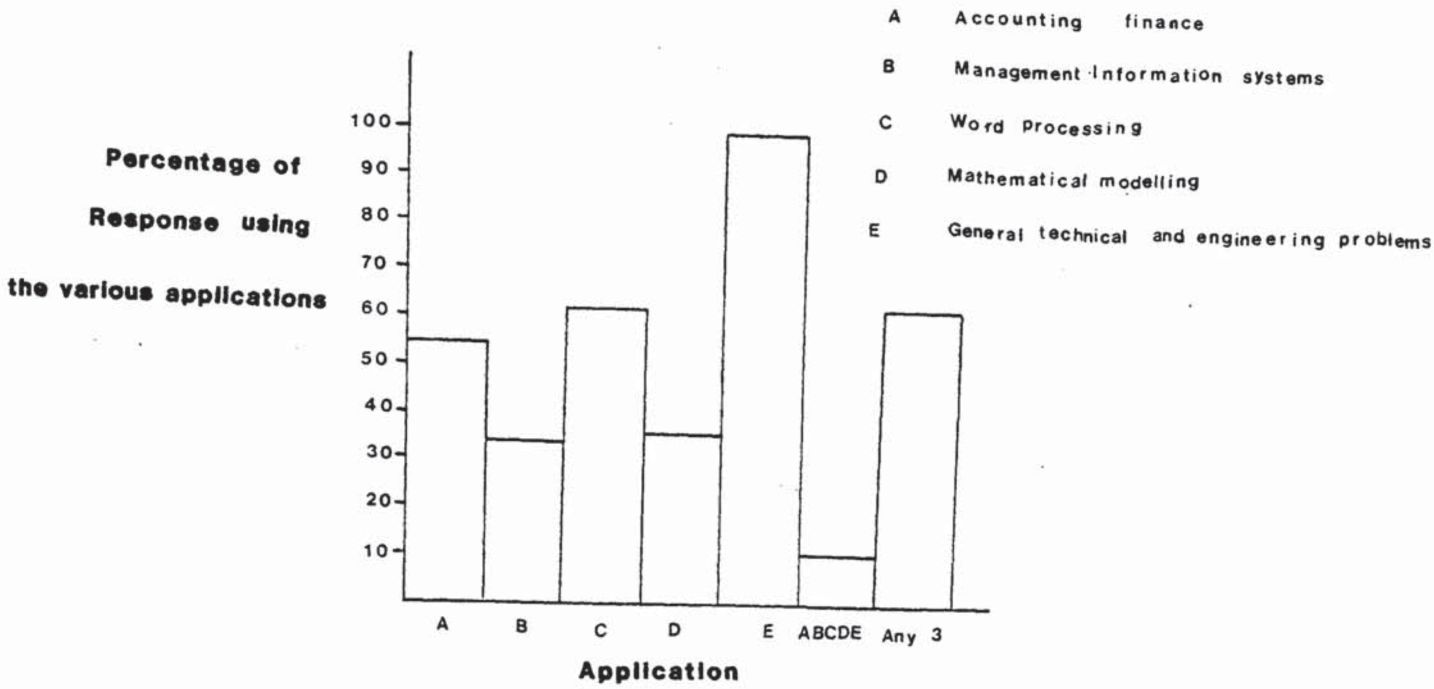


FIGURE 3.3 Common Applications on the Microcomputer.

The use of more powerful systems, including 16 bit microprocessors, powerful operating systems (eg. UNIX) and Winchester disc drives are being advocated by most of the major computer manufacturers and computer journals. The next section on the questionnaire investigated the impact these new, more powerful systems were having on the industry. The type of computer equipment being used was identified to see if civil engineering consultants were keeping abreast of the rapidly advancing technology.

Twelve pieces of microcomputer equipment (including two operating systems) were put forward in no particular order and the respondent was asked to indicate which were being used by their company. The use of 8 bit microcomputers was predominant, as expected but Figure 3.4 also shows that 25% of the companies responding were using both 8 bit and 16 bit microcomputers. The most common operating system was CP/M, with 50% of the respondents using it. UNIX, the operating system developed by Bell Laboratories and implemented on some 16 bit microcomputers was used by only 4% of the respondents. The absence of MSDOS did not appear very important at the time. but the author accepts that it should probably have been included. Figure 3.5 represents a pie chart showing the distribution of the use of various operating systems. If this figure is compared with the use of 8 bit and 16 bit microcomputers in Figure 3.4, it shows that the main operating system to be used on the 16 bit microcomputers is still CP/M. Table 3.2 presents the use of printers by the responding companies, whilst Table 3.3 indicates the utilisation of other peripherals.

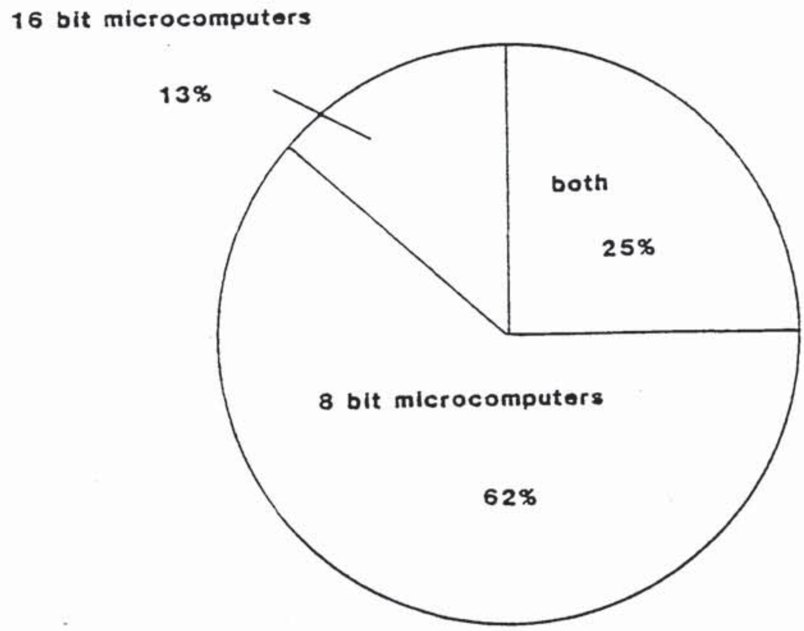


FIGURE 3.4 Distribution of Microcomputer Types.

TABLE 3.2 Distribution of Printers on Microcomputers.

Printer type	Dot Matrix	Daisywheel	Both	Neither
Percentage Used	23	19	40	18

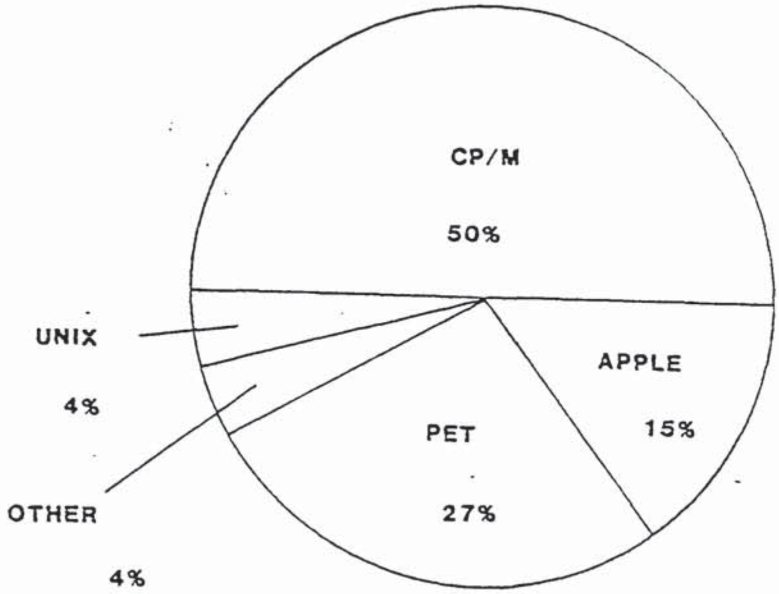


FIGURE 3.5 Distribution of Microcomputer Operating Systems.

TABLE 3.3 Distribution of Various Peripherals.

Peripheral type	Winchester disc	Digitiser	Graph plotter	Light pen
Percentage Used	28	10	26	2

The next question on the form was aimed at identifying the origin of the software being used on microcomputers. Figure 3.6 shows that the number of companies buying in software and those developing software 'in-house' were almost equal. This result is quite surprising since it is generally accepted that good engineering software for the microcomputer is both difficult to find and expensive. One can only assume that most of the software being bought is packages such as electronic spreadsheets, database packages and project management packages rather than actual engineering programs.

Figure 3.7 illustrates the use of computer languages amongst the respondents, who were asked to grade the langauges in a list from those most often used, (5), to those not used at all,(0). BASIC is the major language being used. 92% of the respondents indicated that they used it, with 29% using only BASIC. The percentage of those using assembler was higher than expected and no particular reason can be given for this.

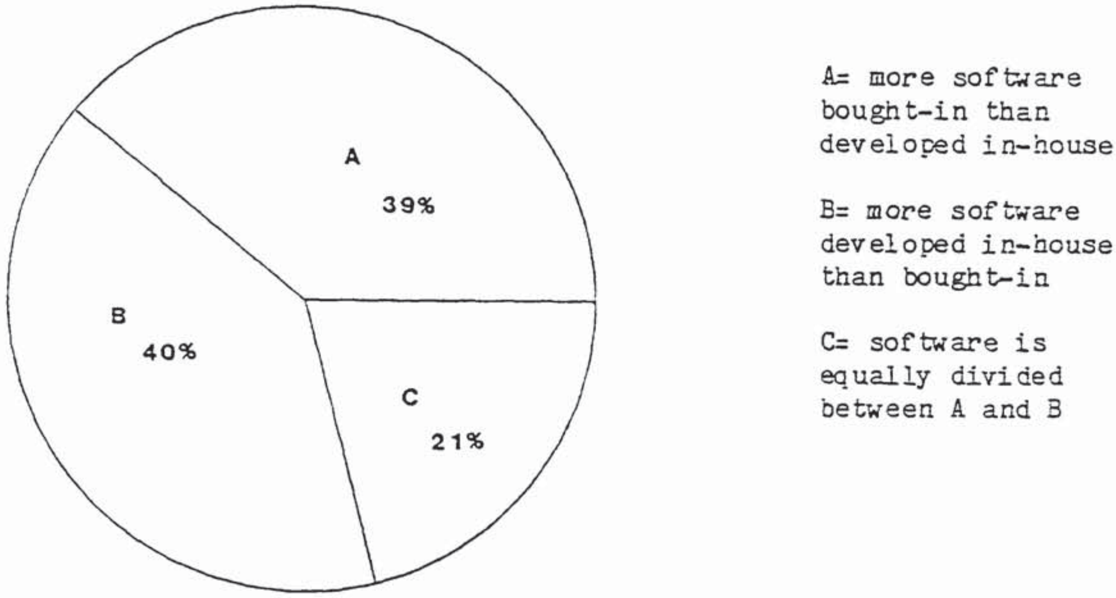


FIGURE 3.6 Source of Software Used.

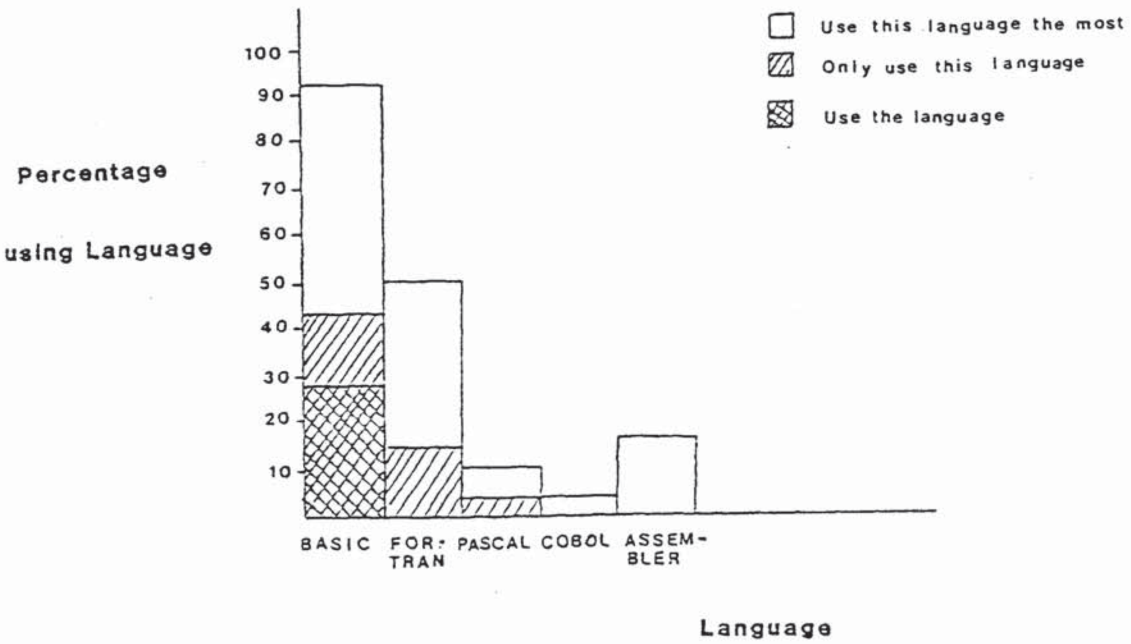


FIGURE 3.7 Percentage of Languages Used.

Finally, many respondents took the opportunity to make their own comments on the state of the microcomputer industry and their company's approach. Some comments occurred several times, the five most common are given below :-

i) Microcomputers are not a cheap option; development costs and time spent on them is high.

ii) There is a lack of good engineering software available for the microcomputer.

iii) Microcomputers have proved themselves useful as machines for data preparation and editing, prior to use on a mini/mainframe computer.

iv) Engineers want to use FORTRAN. With the introduction of larger memories and more FORTRAN compilers microcomputers have become a more viable product.

v) Civil engineering companies are becoming increasingly dependent upon microcomputers.

Most comments stated that microcomputers were regarded as useful tools. Many showed an interest in computer aided draughting packages, but stated that they needed to be improved somewhat before they would make a purchase.

3.4.2 Conclusions of the survey

The high response indicates that there is an interest and awareness of microcomputers, even though the actual 'take-off' of the microcomputer in civil engineering has been slow compared to other industries. Many respondents indicated that one major use of their microcomputers was as intelligent terminals with the company's mini/mainframe or as a link to computer bureaux facilities. This linkage allows them to edit, prepare and transfer data cheaply reducing the cost of the use of the larger systems. Microcomputer hardware costs are extremely low and the cost of the more popular packages now available is reasonable. However, developing software for microcomputers is very expensive, as it is for minicomputers or mainframes. Costs will not decrease in the forseeable future. In fact the cost of developing engineering software for the micro may remain high because the standard of programmer required to make the best use of the more limited facilities available will have to be high.

Microcomputer technology is moving at an extremely rapid rate; over the past five years it has changed from being used at a hobbyist level to now threaten the power of some minicomputers. Although the impact of the microcomputer appears to have been slower in civil engineering than other industries, there is now an obvious awareness and interest in the technology and its abilities. Most companies in the survey now have or are about to acquire a microcomputer of some sort. In hindsight the slowness may not necessarily be a disadvantage since many of the problems of the early systems have been eradicated and some standardisation within the microcomputer industry has been attained.

3.5 Summary

The microcomputer is having some impact upon the civil engineering industry, but methods of choice of hardware and software are poorly documented. In many cases it seems that companies have purchased equipment blindly and have had to pay dearly for experimentation with new technology. Literature on the state of use of microcomputers in UK civil engineering consultancy is quite sparse compared with the American literature available. The lack of literature shows the conservatism of the industry and the slowness in the uptake of new technology. However, the survey showed that consultancies had begun to take an interest. The microcomputer market is fraught with jargon and is often confusing to the beginner. The computer industry also tends to move at a distictly rapid rate, with hardware and software manufacturers entering and disappearing from the market continually. The following work was aimed to produce a reliable methodology for the choice and use of microcomputer and related equipment for the civil engineering consultancy, both at home and abroad. The use of the microcomputer is examined in the broadest terms and guidelines for their use provided.

CHAPTER FOUR THE COMPANY REQUIREMENTS

An outline of the company structure and a typical overseas project are given in the following chapter. From these the actual problems and objectives can be formally identified, using a systems analysis approach.

4.1 Company Structure

Sir William Halcrow and Partners, (Halcrow), is an independent group of consulting engineers which was formed in 1868, but took its present name from the senior partner in 1944. Between 1950 and the mid 70s the civil engineering industry expanded rapidly and the Halcrow workforce grew until it reached around 2000. Since then the amount of civil engineering work in the world has fallen and the workforce has been consolidated to approximately 1100. Of these approximately 700 are professionally and technically qualified personnel. The organisation of the management structure of Halcrow can be seen in Figure 4.1. The Halcrow group has been organised so that the major related disciplines in which services are offered are managed under separate company structures. The group is based in the UK, operating from both Shortlands, London and Burderop Park, Swindon. Most of the work in this research project was carried out in close association with the Halcrow Water company, whose management organisation is shown, in a simplified form, in Figure 4.2. The company deals with water related projects, as its name suggests, and each separate department has its own specialist staff to deal with a particular type of project. All companies within the group are able to call upon the specialist experience contained in the other Halcrow companies. This central backing is an essential feature of the group which allows each individual company access to considerable resources, and provides the

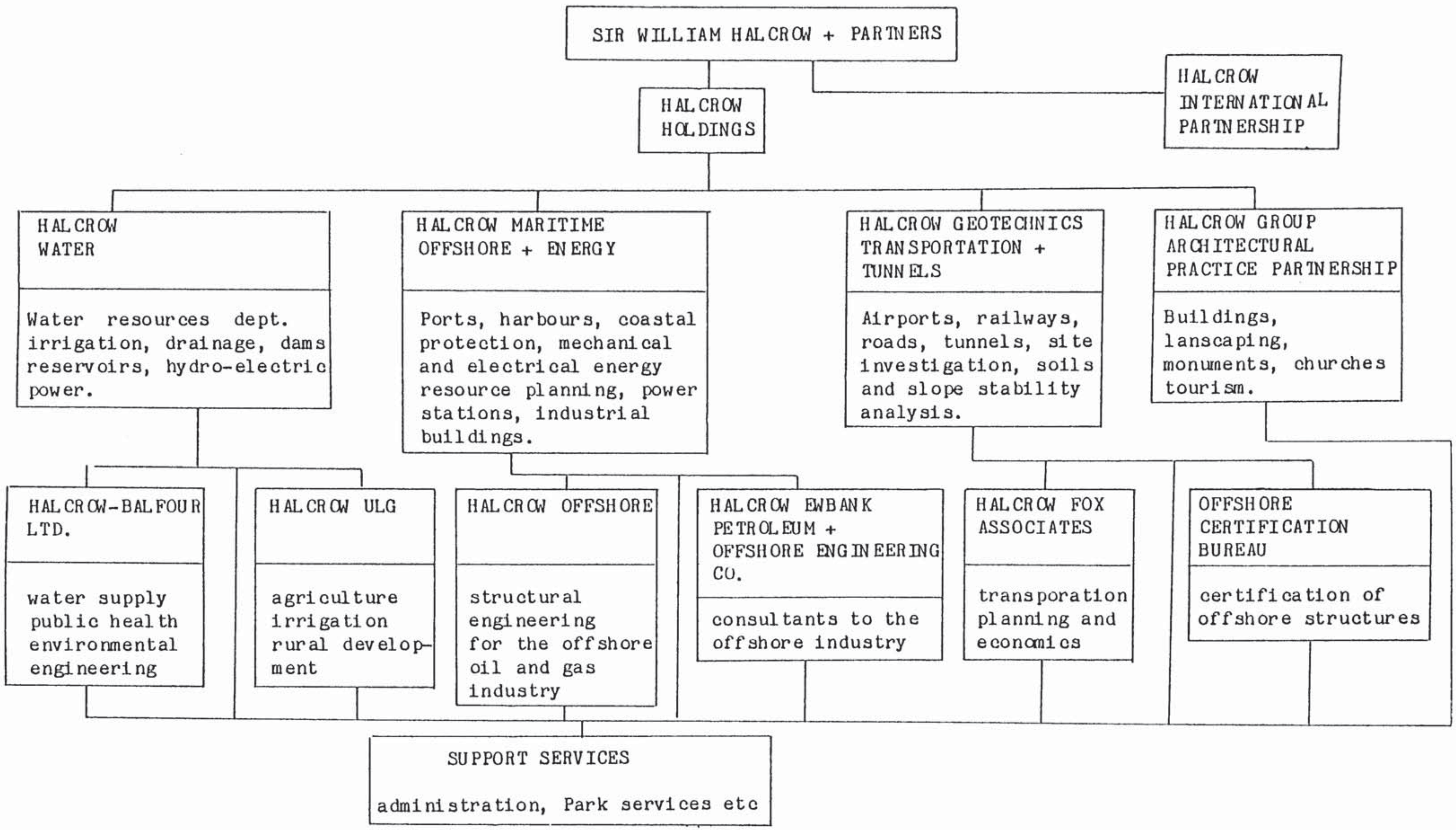


Figure 4.1 Structure of Sir William Halcrow and Partners.

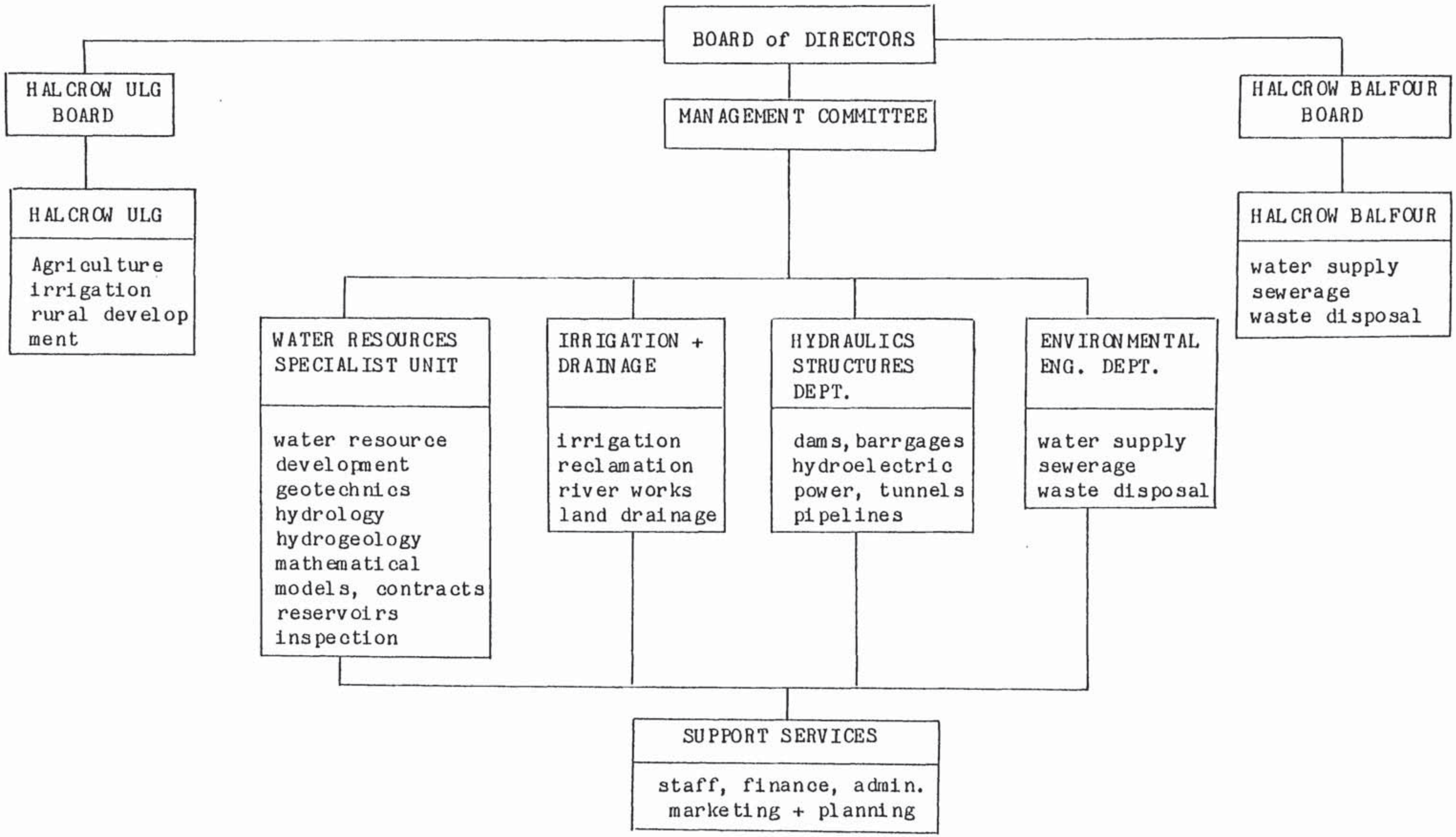


Figure 4.2 Structure of Halcrow Water.

group with a large degree of flexibility. If a project situation arises in which the required expertise is not available within the group it is usual practice to asssociate with other experts or well established consultancy firms able to provide the skills required. It is often common practice to associate with a company based in the country in which the project is being carried out.

4.2 History of Computers in Halcrow

In the early 70s Halcrow began using the facilities of computer bureaux services. In 1976 they aquired a Prime 300 system, using "PRIMOS", Primes' operating system. The system was easy to run, provided simple editing facilities and was cheap in comparison to others such as Dec. Eventually, with Swindon and London offices running Prime 300s it was decided to upgrade the London system to a Prime 750, (due to excessive usage). Swindon had access to the 750 via a telephone modem link.

In 1979, Halcrow Central Computer Services (HCCS) were formed to co-ordinate and manage the effective use of the computers in London. HCCS was headed by the partner from the Offshore division of Halcrow, since they were the largest users of the computer facilities. Several disagreements arose in the London office due to the high cost of computer time and a certain amount of dissatisfaction with computer facilities in the London office was brought to light.

HCCS were constantly making a loss even though they were supposed to be a profit making entity whereas in Swindon the Prime 300 was making a profit and departments were generally satisfied with the service, although demand was often exceeding the available facilities. Consequently some groups decided to consider alternative arrangements to the Prime.

An obligation to break even means that HCCS have to impose significant charges to those who use the central computing facilities, so that engineers tend to use the facilities as little as possible to keep down costs. Reactions to the computing facilities within Halcrow tend to suggest that if a different policy were adopted towards HCCS, many more sections who either do not use the computer altogether or have tended to buy microcomputers, would use the services already available to them. Many divisions are beginning to recognise the fact that if they installed a microcomputer there would be no further costs from HCCS. The existing costing policy seems to be one of the major reasons why divisions were looking towards their own distributed computer systems, rather than using the central system already available. Realistically, HCCS has to remain functional since they provide the means for running the very large programs required by some sections. Many divisions see the answer as being that they obtain there own microcomputer and have the HCCS minicomputers as a back-up when they need them.

The Halcrow accounts department adopted a radically different approach by buying Zilog computers and successfully wrote a suite of programs which they have now made commercially available. The system they use is a Zilog Z8000 with a UNIX type operating system and 10 megabyte hard discs. This system allowed them total freedom in running their software.

In 1981 the Water Resources group also decided to experiment with some form of alternative computing power, investing in a Commodore 8032 system. The main objective of this move was to develop a suite of programs which could be used in overseas projects. Therefore by writing a microcomputer into the project contract, software would be readily available to be used on the overseas site. Within a year the system was being used extensively and a second was bought with a 96K memory. Microcomputers were then already being successfully used by

Halcrow-Fox and Associates, and Halcrow International Partnership in Dubai; both groups using Hewlett Packard systems. A Cromemco system was provided as part of the project equipment on the Irrawaddy Delta survey in Burma and a Commodore 3000 system was also supplied by the client for the Design Drainage Project in Indonesia. On the Master Water Resources and Agricultural Development Planning Study in Qatar the client provided an Apple II microcomputer.

4.3 The Overseas Project

An overseas project can be obtained by various means, including the efforts of worksearch teams and reputation from previous work. If a project is on the 'open market' companies attempt to join the short list, usually by lobbying funding agencies, governments or any other influential bodies. Once on the shortlist a tender is submitted for the job. The tender has to include details of the proposed team members and their curriculum vitae. Usually 5 or 6 companies are chosen for the short list. They are supposedly chosen for one or more of the following reasons:- they have worked for the client previously; or it is the type of work in which they specialise; or it is the size of job normally carried out by that company. A project director is appointed and is responsible for negotiations with the client. These negotiations can go on for varying periods of time. Once a proposal has been accepted the project director continues to be fully responsible, receiving weekly reports from the project manager, and making occasional visits to the team.

The nature of the overseas project has changed dramatically in the past ten years. Previously the company would send one or two people to the actual project site but the bulk of the work would be carried out in the consultant's head office. Today, quite the opposite occurs. In most instances a full project team is sent out to the site and the client usually participates in some form or other. There is often an obligation to provide training for the client and/or the clients workforce.

Costing of a project can be carried out either by proposing a lump sum or by costing outgoings as they arise. The day to day accounting of a project is carried out by the project manager, but the project director is ultimately responsible for charging and costing. A large proportion of the work being carried out by civil engineering consultants are master plan and feasibility studies. The consultant is sometimes required to go on to advise during construction and act as the resident engineer. The consultant's role sometimes takes the form of advisor to the funding agency.

The client often expects the best and most up to date technology to be used on their projects, whilst the consultant has to keep the costs to a minimum. A typical overseas project structure is given in Figure 4.3 but as no two overseas projects are the same, this figure can only be considered as a typical example.

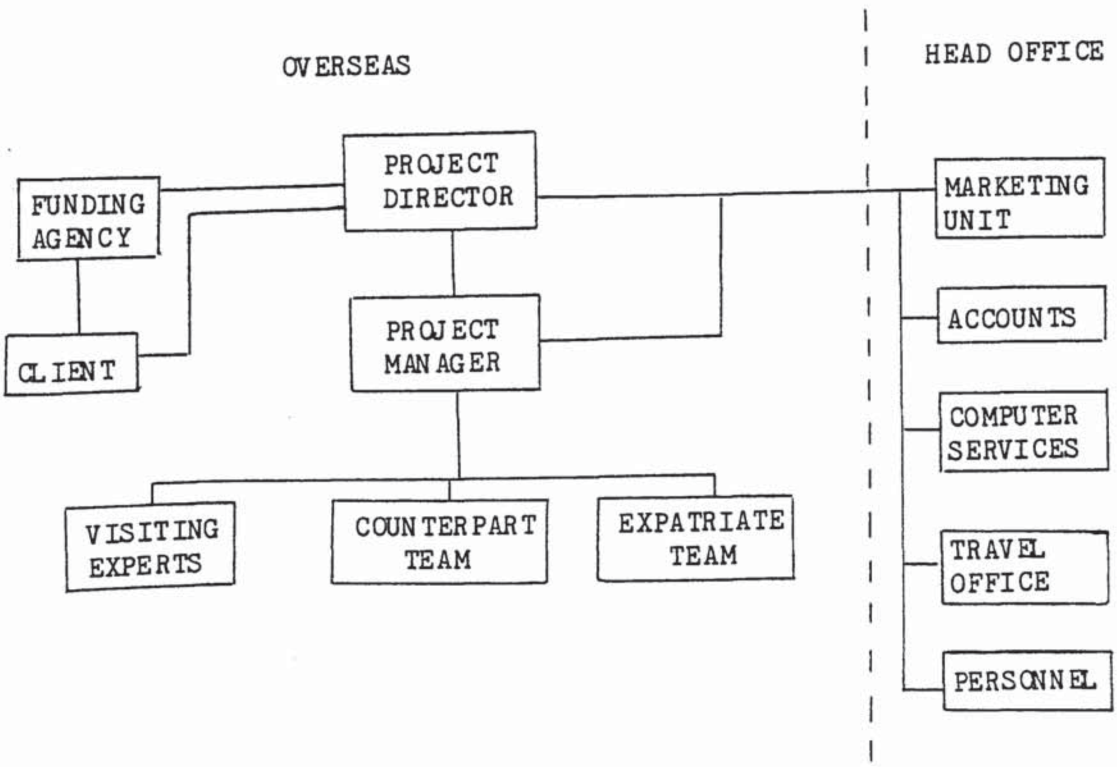


FIGURE 4.3 A Typical Overseas Project Structure.

The inclusion of a microcomputer on an overseas project can come about in a variety of ways depending on the terms of reference. The consultant would normally propose the use of a microcomputer and the budget required would be included in the tender. The client may agree to that figure or may propose a lump sum for all office equipment. If the client refuses to cover the cost of a microcomputer but the consultant feels a computer is needed, then it would probably be provided by the consultant from within his profit margin. In some cases the client would actually provide the computer to be used.

Usually any software bought is charged to the client, and any software developed on site in a client's time specifically for the project belongs to the client. Any software previously developed by the consultant and taken out to the project does not become the clients property. In such cases the consultant needs some way of costing the software that has been developed. The problems associated with software costing are considered in Chapter 6.

4.4 The Project Approach

Initially two major problems were identified. Firstly, there was a lack of policy on the use of microcomputers in Halcrow, in that each separate section within Halcrow had made their own separate decisions as to the type of equipment to buy, the software to be used, etc. These decisions were often made by project managers with little microcomputer knowledge and their decision was often merely based on intuition. Secondly, the Water Resources section envisaged that the microcomputer would be mostly used as a planning tool, developing screening models, and so the feasibility of the use of engineering and planning techniques on the microcomputer was to be examined.

Since the initial problems identified encompassed a mass of inter-related sub-problems, covering a wide range of technical and administrative aspects, a method to place them in a soluble framework was sought, consequently the systems analysis approach was adopted.

4.4.1 Systems analysis

The basic concept behind systems analysis is to take a complex problem and convert it to a several simpler ones, thus identifying definite tasks with direct methods to solving each problem. The actual process of systems analysis is geared to help the decision maker choose the most effective line of action by making a quantitive and qualititive comparison of the alternatives available. The term 'system' is used to describe the overall framework of the theoretical situation being reviewed. The system is examined by constructing a model of the real world situation and the relationships within it.

The systems analysis approach was adopted for two reasons: firstly, it allowed the problem to be defined more precisely in a systemmatic way. Secondly, the systems analysis approach is clearly defined in a stepwise fashion and is familiar to most engineers. In the case of Halcrow Water Company, the systems approach has been a constituent part of several of their recent projects where a master plan study has been carried out, (a master plan is a study where the objective is to define all reasonable alternatives for a given system).

DeNeufville and Stafford (1971) define four basic steps of systems analysis as follows:

- definition of objectives
- formulation of measures of effectiveness
- generation of alternatives
- evaluation of alternatives

Other authors, (for example Cornell,1980) have produced a more comprehensive outline of systems analysis but the above steps always form the core of the approach. Cornell points out that before these steps can be followed it is important that the problems have been clearly defined. It is important that the issues of the project are clearly isolated and the problems correctly formulated before the objectives are tackled. A sufficient amount of time was spent in these initial stages of the project to formulate the work to be tackled and identify the problems that were occurring. It was felt that time spent at this stage would be later compensated by the elimination of inefficiency and redundancy in the project. Figure 4.4 identifies the project plan using systems analysis.

4.4.2 Problem definition

In order to identify the problems two approaches were taken:

1) Various members of Halcrow were questioned as to their requirements and attitudes to the use of microcomputers.
2) The use of the microcomputer both in head office and on overseas sites was examined.

The attitudes of employees varied considerably. More interest in the newer technology was generated in London than in Swindon, this was to be expected due to the concern over existing computing facilities. Nevertheless, the overall attitude indicated a lack of understanding of the technology, of its capabilities, its advantages or disadvantages and its impact outside the civil engineering world. These attitudes were reflected at managerial level as well as at basic engineering levels.

Movement towards the use of microcomputers in Halcrow had been slow. However, in divisions where a microcomputer had been used the reaction was generally one of enthusiasm.

Four main arguments were put forward against the use of the microcomputer :-

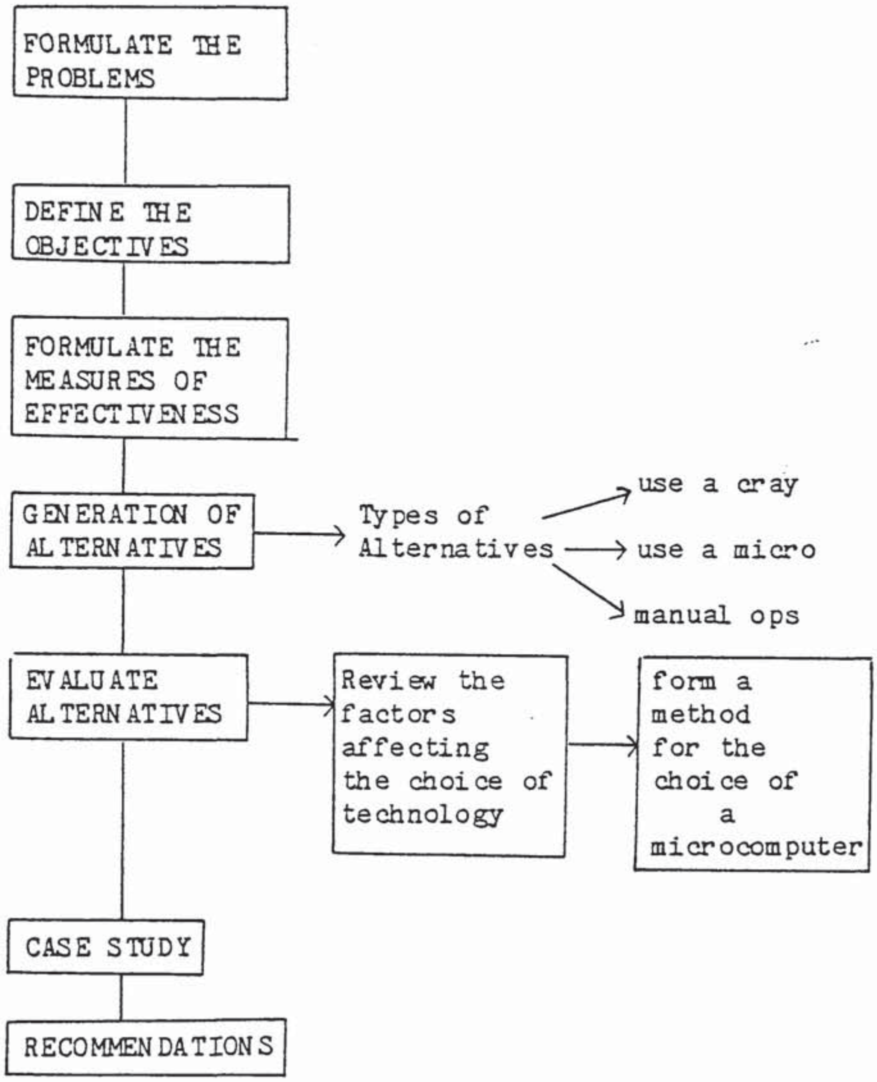


Figure 4.4 Project Plan Using Systems Analysis

1) "Engineers will only use FORTRAN; microcomputers inherently use BASIC, therefore they are of no use."

2) "Microcomputers are not necesssary; Halcrows' Prime minicomputers can cope with all the programming required."

3) "The programs this division uses are far too large for a microcomputer."

4) "Civil engineers should not be used as computer programmers; it is a waste of engineering expertise."

While the above points may have some substance, it should be remembered that :-

a) BASIC is relatively easy to learn and simpler to use than FORTRAN. When developed BASIC was based on FORTRAN, and programmers usually have little difficulty in moving from one to another. The greatest problem with FORTRAN is its input/output facilities which are based on the use of punched cards and reflect the age of the language. The BASIC language offers simple but adequate input/output facilities. Also, once a program has been developed it will not concern the average engineer as to which language has been used.

b) Engineers find it very difficult and costly to link terminals up to the Prime computers when working on overseas sites. Thus, any programming that is required on an overseas project has to be sent back to head office, or carried out manually. Microcomputers could be taken overseas and used on site by the engineers saving time and cost. There is also a large amount of administration/data processing carried out manually on site which could be easily programmed thus releasing a large amount of the project manager's time for actual engineering work.

c) The microcomputer will not be able to cope with some of the large programs Halcrow have developed e.g. 'Sea-Rig' and 'ACAS', (two large numerically intensive programs). The role of the microcomputer is not to take over areas of programming which are efficiently and more economically carried out elsewhere. An ideal solution would be to use a microcomputer and support it with computer back-up from head office when required.

d) Using the engineer as a programmer is often advantageous, especially since he should understand the theory of the problem and the programming is only an extension of this. However, if engineers are to be used as programmers a high standard of supervision must be ensured in order that the software produced is of a significantly high standard. Software must be thoroughly tested and fully documented.

The arguments put forward were not the real problems but merely resulted from the lack of planning, management and understanding. With these arguments borne in mind and with the knowledge gained from the literature, and from the initial investigations the problems to be tackled were defined and are given in Table 4.1.

TABLE 4.1 Problem Definition in the Use of Microcomputers.

PROBLEM	SUBPROBLEMS
Feasibility Problem	What will be the cost-effectiveness. of microcomputers. What effect will they have on projects. What effect will they have on staff. What effect will they have on the client. What should they be used for. What should they not be used for.
Managerial Problem	Should there be a set group policy to use micros. Should there be standard-isation of use - if so at what level.
Understandability Problem	Availabilty of computers. Training. Software availability. Level of expectance from management.

4.4.3 Project objectives

With the problems clearly identified the objectives were drawn up, as follows :-

i) Provide Halcrow with a general insight into microcomputer technology and the state of the art.

ii) Advise Halcrow as to the types of hardware and software which would be most appropriate to their needs.

iii) Identify suitable applications.

iv) Carry out a case study of the use of a microcomputer on an overseas project.

v) Carry out feasibility tests, (for example cost-effectiveness).

vi) Note any trends in the microcomputer industry and attempt to forecast further trends.

vii) Devise a suitable method for selecting microcomputer systems.

The main objective of Halcrow in using the microcompter on an overseas project is one of competitiveness and profitability. With the problems defined and the objectives given above, the measures of effectiveness will be formulated and various alternatives will be proposed in Chapter 5.

CHAPTER FIVE ASSESSMENT OF ALTERNATIVE COMPUTER SYSTEMS FOR OVERSEAS PROJECTS.

The overall effectiveness of any computer system is rather difficult to quantify in workable units, but it can be further sub-divided into:-

- profitability of each project
- measure of client satisfaction
- provision of better solutions to the problems

Although profitability is not the ultimate criterion in the use of microcomputers on overseas projects, meeting the main objective of improved competitiveness will automatically improve profitability of the company. However, the effectiveness of microcomputers on each individual project needs to be measured. It is impossible to measure competitiveness quantitatively, but profitability can be taken as the criterion to be measured. Profitability of a project is reflected in two ways: the reduction in cost to the consultant; and the reduction in time spent on the project, since this allows the consultant to be more competitive in submitting his tenders.

Profitability is based on cutting costs in four areas, namely, manpower, materials, machines and overheads. A consultancy should be able to reduce manpower when using a microcomputer since programs when written, should take over some of the repetitive manual chores. Materials and machines will increase in cost and will have to be weighed against the reduction in manpower and overheads. Overheads should be decreased in the long term.

These measures of profitablility (and competitiveness) by the use of microcomputers will only be positive if Halcrow carefully monitor the use of such equioment and ensure efficiency is maintained wherever possible. It is difficult to convince people to spend more money in certain areas in order to make savings to overall costs and it is therefore important to be able to show the effectiveness of using such equipment. It is very easy to spend large amounts of money on software and software development but if inefficiency and lack of planning are inherent then not only will the expected profits be lost but extra expenses will be incurred.

The whole philosophy of the use of the microcomputer is based on its efficient and well planned use. The microcomputer should be regarded as a tool and like any other tool should only be used for the jobs to which it is most suited.

5.1 Generating Alternatives

The computing requirement for different projects will never be the same and since there is no actual overseas project in mind actual alternative computer systems cannot be generated. Although this research is concerned with the role of microcomputers on overseas projects it was important to look at other alternative computer systems in order to place microcomputer technology into perspective. Table 5.1 identifies the types of system which can be evaluated for a project, the two extremes being represented by the upper and lower limits.

At the lower end of Table 5.1 calculations by hand and the use of calculators are given as possibilities. These represent the traditional methods used which should not be ruled out of certain projects, especially where there is only a small input. At the other extreme there are mini and mainframe computers, various aspects of which make them unsuitable for the consultant to choose for use on the majority of overseas projects. Cost is usually prohibitive but there are many other reasons why they should be treated with caution. Such machines have to be professionally installed, a costly and time consuming process. The Vax 780 for example takes one week to install costing £8000 and the work has to be carried out by a DEC engineer. Maintenance is very important. Mini and mainframe computers require regular servicing and maintenance carried out by service engineers. To emphasise the importance of maintenance take the case of a Data General Eclipse. This computer costs £20,000 to buy second-hand, but the maintenance contract which is essential because of the likelihood of breakdowns costs £1200 per month. Therefore more is spent per year on maintenance than the computer is actually worth. The Cray 1 provides another example. Any company buying this machine receives almost a complete replica broken down into major components for spares, since it is expected to go down every 8 hours on average.

TABLE 5.1 Generation of Alternatives

	COMPUTER TYPE	EXAMPLE	APPROXIMATE COST(£)
UPPER LIMIT	super mainframe	CRAY 1	1million(second hand)
	mainframe	IBM	100,000's
	mini	VAX 750	80,000
	mini/micro	HP100	10,000
	network of micros	ICL	10,000's
	supermicro	Fortune 32:16	6,000
	several micros	osbornes	1000 each
	1 micro	IBM PC	3000
	personal computer	sinclair QL	400
	calculators	HP41C	120
LOWER LIMIT	calculations by hand	-	?

If a computer of the type discussed is taken overseas it would be very difficult to arrange a maintenance contract. There would certainly have to be an agent for the computer in that country. Mini and mainframe machines also require a large amount of management using trained computer personnel. Microcomputers do not require formal installation, nor do they require regular servicing at such small intervals. Moreover, they do not require computer operators to look after them and ensure they are working satisfactorily. If a large system is really warranted a far more complicated method of choice would be required and the client would have to be involved since the system would be a very large investment for the future. Most of the upper part of Table 5.1 is infeasible for the majority of overseas projects. The alternatives to be closely examined therefore comprise of various configurations of microcomputers only.

Moving down Table 5.1 there is an obvious decrease in cost, but there is also a decrease in power and an overall trend for an increase in cost/power ratio. The need for management, (ie professional computer staff), and maintenance decreases likewise. Section 5.2 reviews the principal factors involved in choosing the alternative system for an overseas project.

5.2 Factors Affecting the Choice and Effectiveness of a Microcomputer

There are various factors involved when choosing an alternative for an overseas project; some of which are more obvious than others. Figure 5.1 identifies these factors. In the real world the inter-relationships between them would be far more complex.

5.2.1 Software considerations

The types of application which can be tackled using the microcomputer are numerous. It is really the decision maker's job to identify the requirements of the project and find out whether the

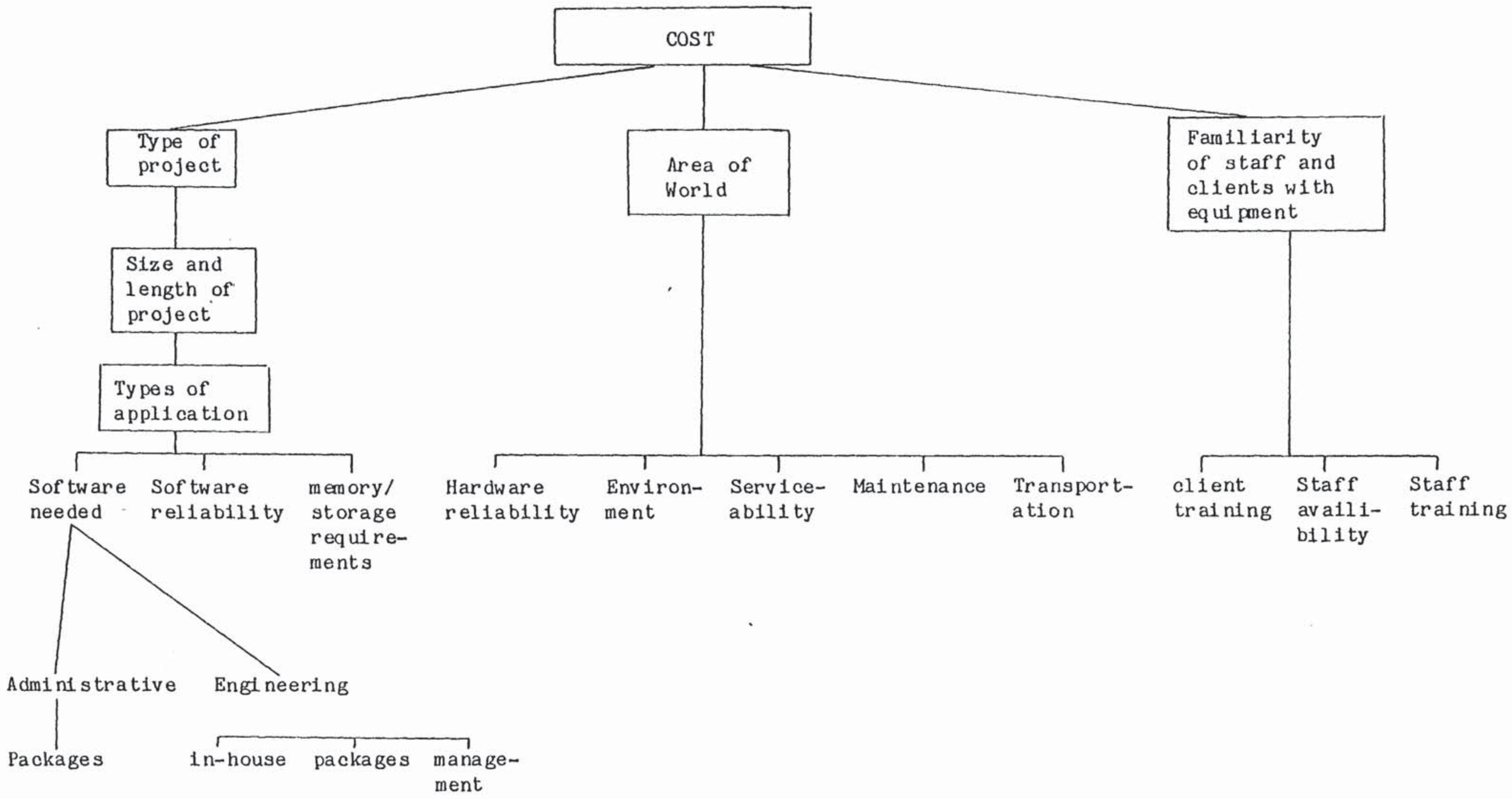


Figure 5.1 Factors Affecting Choice of Microcomputer

software is available or can be written. A list of the most probable applications and the software required for an overseas water project is given in Table 5.2.

TABLE 5.2 Applications for Water Projects

1) Project management
2) Accounting, (costing/project accounts)
3) Word processing, report writing
4) Design calculations, hydrodogy, hydraulics
5) Mathematical modelling, simulation
6) Statistics
7) Surveying
8) Data collection
9) Photogrammetry/digital mapping
10) Soil Mechanics
11) Management information systems, Expert systems
12) Computer Aided Instruction, (CAI)
13) CAD
14) Remote Sensing

Table 5.2 shows the diversity of the work that can be tackled on the microcomputer by the civil engineer. These applications can be divided into two main categories; the administrative chores and the engineering/technical problems.

There are advantages to be gained by using off-the-shelf packages. The cost of purchasing the packages may be much less than developing the software in-house, (the cost of microcomputer software is examined in Chapter 6). Most of the well-known packges, such as Wordstar, DBaseII and Visicalc, have been thorougly tested on the market by thousands of users. A close watch on the amount and types of engineering software available for microcomputers was undertaken over the research period. It was found that the number of companies offering technical software and the amount of software available increased only slightly over three years. Most of the software available is basic structural analysis and simple engineering solutions.

Since most of the packages available are of a business/management nature, the consultancy will have to develop most of their own microcomputer software for engineering purposes. When using microcomputers as part of an overseas project such development may be an advantage. Since the consultant is often expected to leave some level of knowledge with the client once the project is complete, programs can be written with this in mind. Program listings can also be obtained, whereas with many bought-in packages source listings are not available. However, if a software package exists for the application needed, then in most cases the user is well advised to buy it. It is not economically feasible to "reinvent the wheel". As a rule it is always best to have had the package thoroughly demonstrated before purchase. It is also useful to view the documentation provided with the package.

When buying well-known software packages produced by the better known software houses such as Pulsar and Microsoft a high standard of quality can be expected (although the elimination of all bugs cannot be guaranteed). When writing software to be used on civil engineering projects, high quality has to be assured. There have been cases, particularly in the USA, where programs have produced wrong results and errors in construction have occurred. In these situations there is a problem of responsibility and liability. At present it seems that liability lies with the body actually using the program not the body that wrote the software, although a test case has not yet occurred.

Therefore a consultancy which is writing and using its own software developed for a project must ensure that certain standards in quality are maintained.

Software quality is governed by several factors, including software reliability, portability, performance and maintainability. Each of these factors is difficult to measure quantitatively, although techniques exist to do so. The concept of software reliability and reliability measurement are controversial topics. Many techniques have been put forward to evaluate software reliability, ranging from probabilistic techniques, to the estimation and prediction of software performance parameters. However, traditional reliability concepts such as "mean time between failure" are meaningless for software. Software fails due to inherent design/implementation faults and not fatigue.

Several characteristics exist in a program which contribute to that programs reliability, these include :-

- the program should be error free
- the program should be easy to understand
- the program should be well defined
- the program should be easy to test
- the program should be easy to amend
- the program should be efficient and easy to operate

By adopting a general problem solving approach in the software development process the above characteristics can be achieved. The following phases should be identified during software development :-

a) SYSTEMS ANALYSIS - the problem should be defined and understood but no attempt to solve should be made.

b) DESIGN PHASE - translate the problem and its requirements specification into a conceptual solution. Design techniques such as flow charts or decision tables should be adopted. Computer specific considerations should also be made, e.g. which computer, which language etc.

c) IMPLEMENTATION - design the solution from the previous phase, i.e. translate into computer readable form

d) DEBUG and TEST - the program should be carefully debugged and thoroughly tested.

e) MAINTENANCE

It is important to remember that correctness, (i.e. freedom from errors) and reliability of a piece of software does not necessarily mean that the actual requirements have been achieved. Software reliability cannot be achieved by any single means, but is the result of co-ordination of development efforts, (Sommerville, 1982).

Portability is a measure of the changes that necessarily have to be made to programs in order that they can run on different machines. The less change the greater the portability. Clearly, maximising portability in programs is highly desirable, since this will reduce costs (manpower and time) of converting the program to use on other machines.

One of the, supposedly, main advantages of a high level language, e.g. FORTRAN, PASCAL, is that the user program can be transported to different machines. However, this ideal is invariably not completely realised. In Figure 5.2, L_x and L_y represent two dialects of the language L. L_x runs on machine C_1 and L_y runs on machine C_2. The unshaded area is part of the programming language which will run on both C_1 and C_2 . The shaded areas are incompatible to the other computer system. Although standards exist for all high level languages, dialects are still created. Dialects are usually due to the implementor omitting or modifying certain features of the language to ease the task of implementation on a particular system, or trying to "improve" the language.

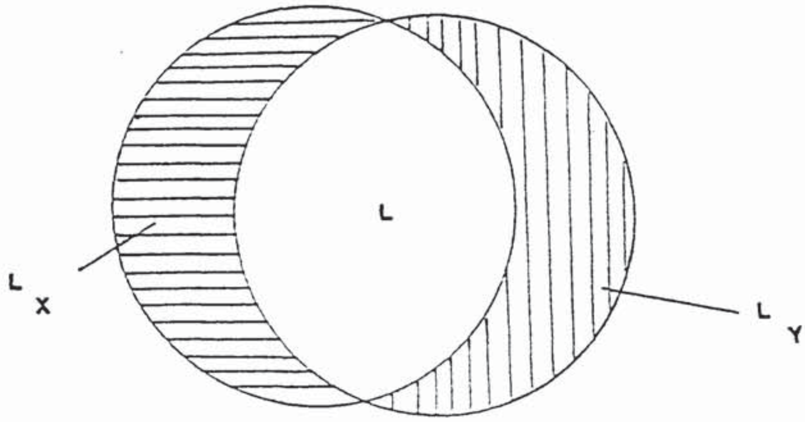


FIGURE 5.2 Representation of Language Dialects.

Performance of programs will depend a great deal upon the language being used and the processor being used. Appendix C shows an experimental program, typical of benchmark programs used by manufacturers and computer reviewers, run on several machines in different languages. The results given in Table 5.3 show the vast difference in performance in certain areas of the program but results can only be taken as indicative. Disc access speed and screen addressing should also be taken into consideration since they can severely affect performance.

TABLE 5.3 Measurement of Computer Performances.

Microcomputer / Function	BBC BASIC	PET BASIC	OSBORNE MICROSOFT	IBM PC	APRICOT MSBASIC
LOOP	12	16	15	13	14
ADD	21	46	35	36	40
COSINE	4m20	6m10	2m35	3m48	4m25
TANGENT	7m43	9m27	4m56	6m01	7m16
DIVISION	24	1m26	30	32	35
GOSUB	11	27	24	24	15

Maintenance of programs is one of the most under-esti.ated and costly areas of software production. Use of high level languages should reduce the need for, and cost of, program maintenance since they are easier to understand than machine code or assembly languages. Maintenance is made particularly difficult where staff turnover is significant and inconsistency is large. Maintenance is, therefore, very dependant upon good program documentation.

Documentation, although one of the most important parts of software development, is invariably left until the program has been completed and running for a while, or even forgotten altogether. Documentation is a process which should be carried out as the program is designed, not once the program is finished and tested. Design flaws can often be due to inadequate documentation, and can be very difficult and time consuming to find.

It is essential that a documentation package should be written for others to use, ideally the package should include :-

i. An english language description of the problem.

ii. A flow chart (or chart of a similar type).

iii. A symbolic listing of the program.

iv. A list of instructions required to operate the program.

v. A description of records and file layouts, (if applicable).

vi. An example is often useful.

vii. A list of error conditions.

A form of internal documentation is also useful, this should include :-

1. Title and filename

2. Brief summary of what the program is doing.

3. Meaning of variables used.

The better the code the less comments are required. High level structured languages can be written to be far more self-documenting. Documentation should be totally independant of hardware and software. Advanced technology will not change documentation. Documentation is of the utmost importance since it will be applicable for the future life of that program and can enhance the ease of updating a program. One of the most important aspects of documentation, which is often totally ignored, is that when the program is changed the documentation must also be appropriately changed. It is useful to keep the documentation on disc as close to the program as possible in order to make changes easily.

In engineering applications the two most commonly used languages are BASIC and FORTRAN. Engineers tend to prefer FORTRAN. This preference was a major factor in the slowness of using micros since they are inherently BASIC computers and it is only since 1982 that other languages have become readily available. The following list represents the main criteria to be taken into account when choosing a programming language,(these are not given in any particular order):-

1. Ease of learning
2. Cost (of language and training)
3. Adequacy of I/O facilities
4. Ease of interface with other languages and databases
5. Speed of compilation/interpretation and execution
6. Diagnostic aids during compilation/interpretation and execution.
7. Program speed and memory requirements
8. Portability - ability to run on other machines
9. Nature of application
10. Languages already in use at the establishment

Generally, FORTRAN is compiled whereas BASIC can be compiled or interpreted. Execution of a compiled program is faster than interpretation since a compiled version of the correct program is saved and run whereas an interpreter goes through the whole program line by line each time it is run. However, it is sometimes useful to develop the program using an interpreter then save a compiled version using a compiler for the same language. The overall edit- compile - run cycle using an interpreter is often fastest.

Diagnostics supplied by compilers and interpreters both during the initial interpretation of the program and during execution will depend upon the language package itself. Some software manufacturers have a better reputation than others for providing diagnostics. In some cases the compiler has to be fitted into a small amount of memory and diagnostics are often the first part to be cut down.

Memory requirements again will depend upon the version of the particular langauge being used, but in general FORTRAN and PASCAL will require more memory than BASIC. Program speed obviously depends on the nature of the application and how skillfully it has been written, but it will generally be faster using a compiler than an interpreter.

Basically the choice of language will depend upon the application being tackled and the ability of the programmer. It seems common sense for companies to be as diverse and flexible as possible and make the most of the individual assets of the languages available to them.

The decision maker will often be the project manager, who should have a good idea of the types of application which the project team will require. Whether those applications are predominantly administrative, engineering or a mixture of both he will need to estimate the maximum amount of internal memory and the number of computers required. It is difficult to produce a method to estimate computer requirements in terms of memory, backing store and number of machines. These will depend upon the type of project being undertaken and the consultant will be able to assess these needs more accurately once experience has been gained with microcomputers.

5.2.2 Area of the world

There are factors affecting choice which are especially important when dealing with the use of microcomputers in overseas countries, particularly third world countries where standards are not the same as those found in the UK or other western countries. For example, the applications being evaluated in this investigation require a high standard of reliability, since breakdowns in the overall system on an overseas project would prove intolerable. Hardware reliability is a condition which is difficult to quantify and literature on the reliability of microcomputer systems is scarce. Often reliability of a system is tested on hearsay. However, microelectronics have a very good reputation for reliability, and some companies claim their products can be employed for several man-years without any problems. Electro-mechanical devices do not enjoy such a high reputation.

There are certain measures which can be taken to improve reliability, e.g. standardisation of circuit boards, standard sockets etc, which would enable maintenance to be carried out by direct replacement of a module, an advantage over returning the whole system to an agent to be repaired. There are several self diagnostic and monitoring systems on the market to aid the user. In many cases a high level of expertise will still be required to use such equipment and this will become more costly as technological sophistication develops further. Four factors to note which will have an effect on reliability and ease of maintenance are:-

1) Choose a machine with a modular design
2) The electronics should be well protected by a robust case
3) Self diagnostics routines are useful
4) Obtain good original equipment manufacturer (OEM) manuals where available.

Environmental factors include humidity, temperature, dust, voltage and transportation. All computer and peripheral manufacturers provide the tolerance limits of their equipment, an average representation is given below:-

Humidity :- 20% - 80% non-condensing.

Temperature:- 4^0C - 49^0C.

Voltage:- 100, 115, 200, 240. (50/60HZ).

In overseas offices where climate is not conducive to normal operation an air conditioning unit is essential. Where voltage is uncertain and/or power failures are likely a voltage regulator and back-up battery pack may be necessary. On many projects where a microcomputer has been used by Halcrow, they have been able to buy reasonably priced regulators in that country thereby relieving the problems of repair, servicing and transportation, particularly the latter since these units are often rather heavy.

In areas of the world where the environment is not conducive to normal operation and where service and repair is a problem, self maintenance is one form of prevention of total loss of a system. There are preventative measures that can be taken in order to ensure the smooth running of a system on an overseas project, such as:-

a) Always carry cardboard cutouts or old discs in the disc drive during transportation.

b) Always close disc drive doors during transportation.

c) Keep the equipment in one place whenever possible.

d) Keep the equipment in an air conditioned room where possible.

e) Keep the equipment clean.

f) If the top can be removed keep the interior free from dust by lightly brushing with a soft paintbrush.

g) Only allow experienced personnel to open or interfere with the computer.

h) If equipment is being used for long periods of time in a hot environment employ an extra fan to keep it cool.

Servicability is largely dependent upon the area in the world in which the project is being carried out. If an agent for the equipment does not exist in that country the consultant would either have to send it to an agent in the closest country or return it to the UK for repair (the latter probably being a safer approach). A survey of computer manufacturers agents in overseas countries was carried out. The results are given in map form in Figure 5.3. A sample of 20 computer manufacturers were asked for this information but many felt they were unable to answer because of the fear of competitors. They would only divulge such information if there was a definite interest in buying their equipment.

5.2.3 Familiarity with the equipment

When choosing a system the decision maker should note the ability and familiarity of his team with computers. The ability to choose equipment with which project team members are already familiar would be a definite benefit since time would be saved in training on site.

Often the consultant is required to train the client with any new technology used on an overseas project. If microcomputers are to be left behind for the clients to continue to use some form of training must be provided. This approach will require consulting staff who are very conversant with the hardware and particularly the software of the system to train them.

Recommendations were made to Halcrow in the early stages of this research that some form of training would have to be provided if an

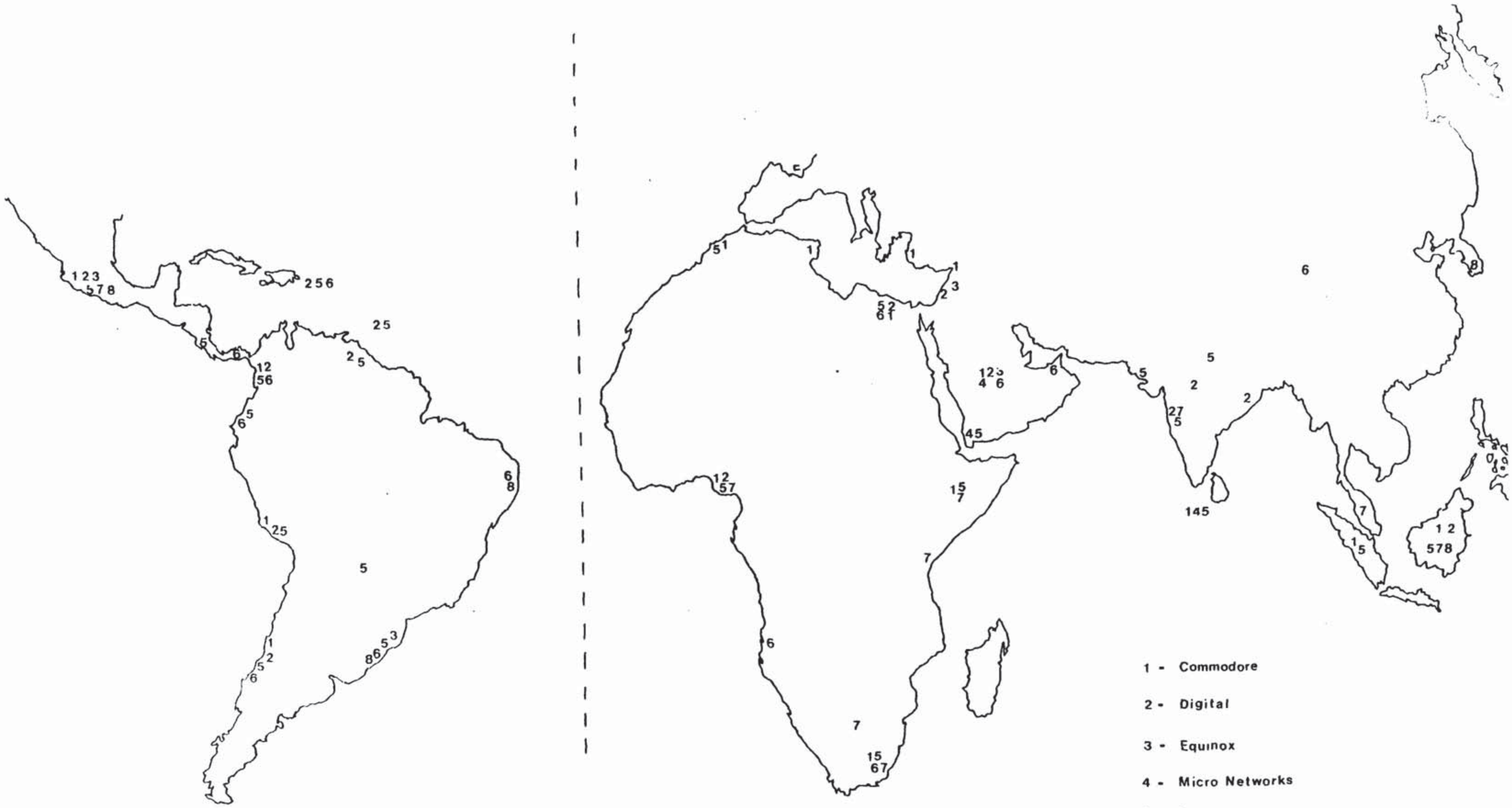


Figure 5.3 Computer Agents in Overseas Countries

engineer was to be expected to cope with the use of microcomputers on site. Various forms of training are available to the consultant. There are several educational packages on the market which teach programming and other aspects of computing. There are other forms of self tuition including purpose written books, or merely giving the tutee the manuals and letting him work his way through them. These self tuition methods can often be long winded and not very fruitful. A company may be able to set up their own training course, this will depend upon the availability of experienced personnel. It is often more appropriate to send staff on a training course away from their normal working environment. The training then becomes a separate activity and not an extension of the days work. There is also less risk of staff on the course to be called away for work reasons during training. The type of training course that is required will depend on the overall experience of the staff. A general introductory course is usually appropriate to begin with, then courses can take a more specific direction according to the requirements of a particular team. If staff do not use computers frequently most will forget computer techniques and periodic refresher courses may be needed.

In some cases the client may already have a particular computer, or have had some introduction to a particular computer manufacturer and therefore ask the consultant to supply specific equipment. For this reason it is important that Halcrow become acquainted with various computers and software packages and increase their flexibility.

If the equipment is to be used by the client in a counterpart role and if it is to be left on site once the consultants have finished the project then some form of client training will be required. In many cases this will require a person who is separate from the actual engineering on the project to prepare and run courses for the client. That person will have to be very experienced with micrcomputers and microcomputer training. He will also have to be prepared to be very patient with the clients since such technology wil be very new to some of them and take a lot of assimilating.

5.3 A Methodology for Choosing a Microcomputer

A flowchart is given in Figure 5.4. By working through the chart five lists should be organised as follows:-

a) A list of packages and languages.

b) A list of hardware components.

c) A list of project team experience with microcomputers.

d) A list of computer agents in that country.

e) A list of clients preferences (if they have any).

For example, when deciding upon hardware components the list might contain:-

1) COMPUTER
- expansion capability
- ability to run peripherals
- ability to run other machines software/discs
- physical characteristics e.g. robustness
  style of keyboard
  screen size/colour
  disc drive capacity
  input/output facilities
- portability/weight
- memory
- cost

2) PRINTER
- size of buffer
- speed
- quality of print
- character set
- dot matrix/daisy wheel
- cost

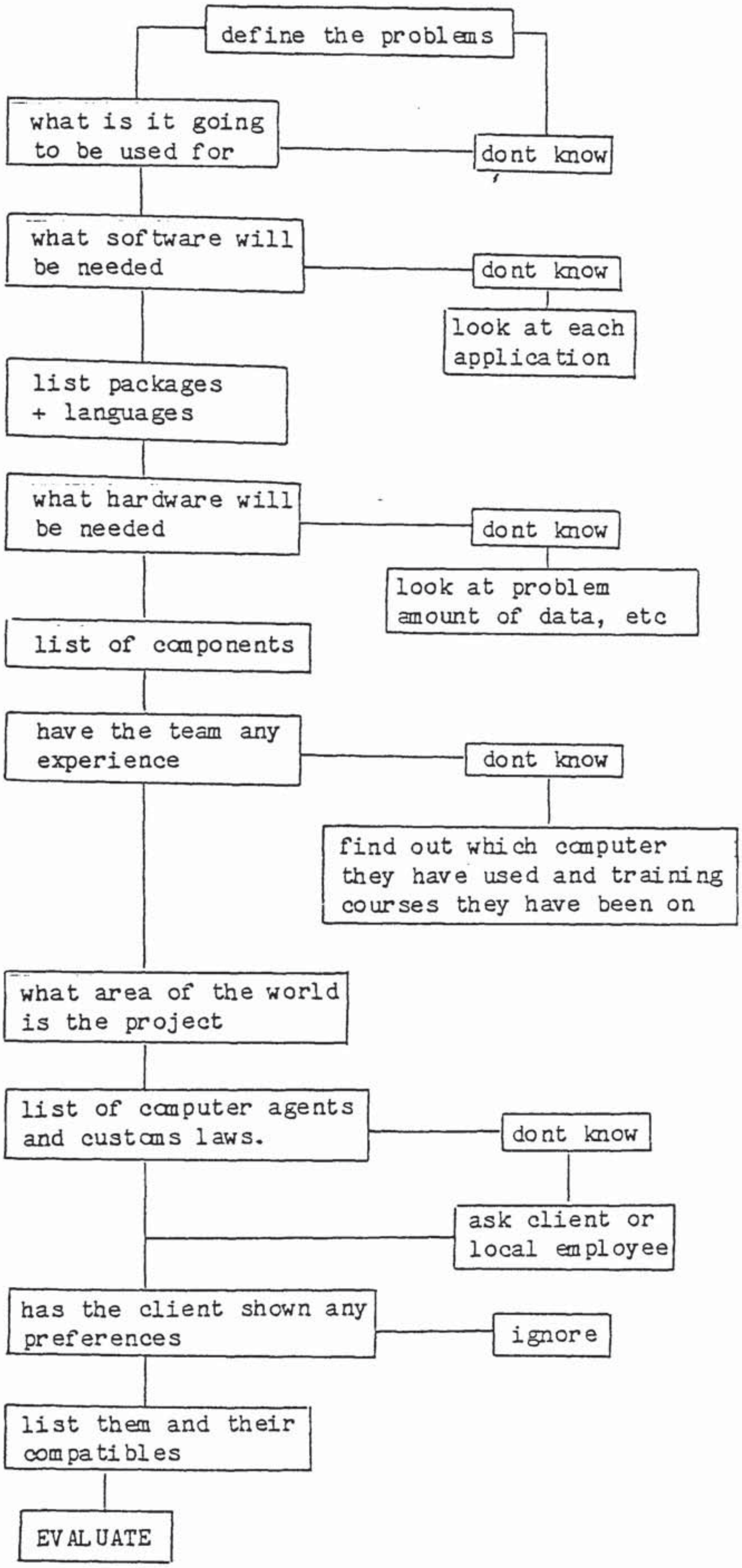


Figure 5.4 Method to Choose a Microcomputer.

Once these lists have been completed a general picture of the system required will have been obtained. From here five or six computers should be found within the allocated budget which generally meet the requirements laid down. Taking each computer at a time, they should be examined using the lists produced. A point system can be used, so when a computer meets a particular requirement on a list it is given a point. Some lists may be more important than others according to the project being tackled, in this case the lists should be weighted and the points geared to that weighting system. For example, on a short term project the team experience may be considered to be more important than the facility of having computer agents in the vicinity. Therefore the team experience might be given twice as much weight as the computer agents. However, on a larger project more emphasis might be put upon the availability of computer agents in that country, to facilitate maintenance and other queries.

The points for each system should be totalled and the one with the largest score will be the system meeting requirements closest.

5.4 <u>Summary</u>

The overall limiting factor when choosing a microcomputer for an overseas project will be cost. On each project a certain budget will be allocated. Many projects are in third world areas and are involved in developing master plan studies for the client. Such projects are often funded and overviewed by various external funding agencies, and so budgets are tightly controlled and the cost of a computer would be a limiting factor, however aid organisations are recognising the benefits of using such technology more and more. It has been previously stated that if the client/funding agency will not provide a budget for such equipment, but the consultant feels that a microcomputer is warranted for that project then the consultancy may provide the equipment. Again, the choice would be made with certain financial limits, but it would be retained by the consultant along with any software bought or developed.

During the past five years the power and sophistication of microcomputers has increased at a very rapid rate whilst cost has been kept extremely low. Even so, it seems that the movement towards the use of microcomputers in the civil engineering industry in the UK has been slow, much slower than other branches of engineering. The major factor contributing to the slow take-off in civil engineering appears to be the lack of good engineering software. Therefore the two major factors in the choice of microcomputers for overseas projects from the consultants point of view is the cost of the hardware and software and the the availability of applicable software, particularly technical software. From a funding agents and clients point of view the major criteria should be whether the microcomputer is appropriate, whether it will provide them with benefits both during the project and once the project is over, and whether they will be capable of using such equipment once their consultants have left. The use of microcomputers on overseas projects will be examined in Chapter 6. The costs of using a microcomputer and a cost-benefit analysis will also be assimilated.

CHAPTER SIX USE OF MICROCOMPUTERS ON OVERSEAS PROJECTS

Halcrow are interested in using microcomputers 'on-site' in overseas countries, particularly developing countries where most of their work is concentrated. This chapter is an overview of two overseas projects and their use of the microcomputer. Both projects were "master plan" studies being carried out by Halcrow in Bangladesh: a water resources project and an energy project. In each case the computer requirements and the emphasis on microcomputers was quite different. The use of microcomputers and the philosophy behind doing so was examined. Whilst in Bangladesh the opportunity was also taken to examine computer systems being used by other bodies such as the United Nations agencies and the Bangladesh State Institutes.

Section 6.1 discusses aspects of the Water Resources Project and the Energy Project is reviewed in Section 6.2. In both sections the microcomputer applications being implemememented were examined. Section 6.3 gives an overview of the state of computing in Bangladesh. Section 6.4 looks at the feasibility of using microcomputers on such overseas projects.

6.1. The Water Resources Project

The Water Resources Project constitutes a master plan study of the Ganges and Brahmaputra Basins. The Rivers Ganges and Brahmaputra are highly seasonal, producing extensive flooding in India and Bangladesh in the monsoon season. In the dry season, the flow of the Ganges can fall to five per cent of its maximum. Bangladesh suffers the worst of both extremes. During the monsoon season, as much as a third of the country can be inundated, whereas in the dry season there is not enough water to meet the countrys needs. The lack of water during the dry season in Bangladesh was further worsened by the construction of the Farraka barrage on the Ganges by the Indian Government. The barrage allows the Indians to divert large amounts of water during the dry season leaving less flow to Bangladesh. The Water Resources Project team is not only trying to assess an overall picture of the water situation in Bangladesh, but is also looking at the feasibility of several possible construction projects on the Ganges and the Brahmaputra. Such projects are intended to provide flood alleviation during the wet season and an increased flow during the dry season. The political nature of the implications do not allow these aspects of the work to be discussed in any more detail. However, this restriction in no way impairs the evaluation of microcomputers on the project.

6.1.1 The microcomputer system

Within the proposals for the project, Halcrow put forward the recommendation to include $5000 in the budget for computer facilities. The machines that were purchased and any subsequent software developed during the course of the project would be the property of the client, and would be left with the Bangladesh Water Development Board at the end of the project. The project team showed a preference for the Osborne microcomputers, one of which had been recently installed in Halcrow, Swindon. Three main reasons existed for this preferance-:

1) PORTABILITY - at the time it was the only microcomputer on the market which offered portability as well as the system facilities which are normally expected with a business machine.

2) COST - the Osborne microcomputer was being sold at a very competitive price, with a large amount of useful business software free.

3) OPERATING SYSTEM - the CP/M operating system was regarded as an industry standard by the project team. Large amounts of ready made software is available and most is of a highly credible standard.

The complete microcomputing facilities in Bangladesh consist of three Osborne microcomputers, one 12" monitor, one Epson MX100 dot matrix printer, one Olivetti Praxis typewriter/printer, one 5 Megabyte Winchester disc drive and one voltage regulator, all of which are kept in air conditioned rooms. The three computers are in almost continuous use from 9 am to 8 pm by either Halcrow or client staff, with two machines being taken home most evenings by members of the Halcrow staff. The Water Resources Project was the first Halcrow team to use a CP/M based system on-site. Halcrow had little experience with either the computers or CP/M, so that back-up could not be expected from head office. The machines were sent to Bangladesh at the same time as the arrival of the project team and subsequently, there was a total lack of familiarity with the systems. Two of the four Halcrow staff tended to use the computers intensively. These were the Project manager who had previous experience in setting up a microcompter system overseas and wide FORTRAN programming experience; and a Water Resources Engineer who had previous FORTRAN programming experience on the Prime 750, and the VAX 11/750. and had also used VisiCalc and BASIC on the Commodore PET. The CP/M system was very new to both users and it took time to become familiar with it.

Since the machines were there as part of the client's equipment, the clients representatives were actively encouraged to use the computers. However, there was no requirement in the terms of reference of the project to provide training for the client staff. Due to the constant pressure of work the Halcrow team had little time to formally train the Bengalis. Most of the Bengalis using the systems had some previous experience on a computer, mainly the Bangladesh University machine (an IBM mainframe). Two of the part-time Bengali staff were systems analysts/programmers from the Bangaldesh University of Engineering and Technology. Some of the Bengali staff were using

Supercalc, (an electronic spreadsheet package) and a Bengali secretary had been taught to use Wordstar, (a word processing package).

6.1.2 Water applications

Several applications packages are supplied upon the purchase of an Osborne microcomputer. Those proving to be the most useful were Wordstar, Supercalc and Dbase II, (which is not usually included free of charge). FORTRAN80 was the the most used language, BASIC was used very litle.

The Wordstar package can be used for word processing and for inputting and editing Fortran and Basic programs. The package is simple to use and the facility of running programs from within it is a worthwhile asset.

Dbase II, has been extensively used throughout the project, as a means of inputting and storing data in an orderly and useful fashion. It has allowed information from many sources to be collected and collated. Once data has been entered and collated using Dbase II there is the facility to allow the data to be used by other programs written in FORTRAN, BASIC etc. This facility was succesfully used and proved an extremely powerful feature. Using this package grid maps of $1/2^0$ by $1/2^0$ have been produced to illustrate factors affecting the region under investigation e.g. landuse, land capability, rainfall, topography, meteorlogy. The main disadvantage of Dbase II is its total lack of trigometric functions, which poses a problem in some engineering and technical applications.

FORTRAN was the major computer language being used on the project, and although it was used extensively there were several anomolies arising from the input/output routines and format statements. These will be further discussed in Section 6.1.3. In most cases the FORTRAN Programs had been taken from the Prime/Vax systems at Halcrow (Swindon), and alterations carried out. These programs fall into two types: those which are fairly small and straightforward and only require minor alterations; and those which have had to be completely re-written in order to conform to the memory restrictions of the Osborne. For example CONCOST, a costing program developed by Halcrow, which originally had dimension statements of 30,000 - this obviously could not be put on to the Osborne in its original form, due to memory restrictions.

Supercalc had been used mainly for accounting/project management type applications, e.g. man-hours, plant cost etc. It was noted that if data could be passed to and from Supercalc for use in other programs, as one can with Dbase II, it would have been a very useful additional feature.

6.1.3 Software and hardware problems arising

Two problems which are inherent to the Osborne microcomputer are the screen size and the lack of an internal fan. It might have been thought that the smallness of the screen and the limitation of 56 columns would have produced some complaints from users. However, the project team and their Bengali counterparts had accepted the limitation and several reports of using the machines for many continuous hours with no recognisable adverse effects were noted. The 12" monitor was seldom used. As the Osborne has no internal fan, the machines would become very hot during constant use, as would the floppy discs. There were occasions when the machine, if too hot, would produce screen failures. When this occurred the machine had to be turned off for a while. This failure did not occur too often since air conditioning was operating continuously during the use of the micros. However, at night the air conditioners were turned off, leaving the machines in a humid room. Although problems of condensation may have been expected it seems that since the Osbornes were already warm the build up of heat in the room did not cause condensation. (In fact, if the machines had been fan cooled there may have been problems with condensation.) Overall effects of humidity are always difficult to assess quantitively, and could only be done properly in controlled laboratory conditions.

Two major hardware problems were continually arising, with the disc drives themselves and the crashing of floppy discs. One of the computers had to be immediately returned to the UK because of a disc drive failure, which may have been due to its mode of carriage, since it was transported in the hold of the plane and not as hand luggage. The three micros had been in use for approximately nine months and the disc drives were starting to show signs of deterioration. The discs were of good quality and were not causing any problems in the UK. However, the project team had collected 30-40 discs which gave the CP/M message "BDOS error - bad sector" when the user tried to load any software or boot the system. Obviously discs can fail due to many problems, such as temperature, humidity, dust, dirt bad handling, storage etc.. No single factor could be isolated as the cause of the failures that were occurring. Some discs had lasted the course of the project, others failed after being used once or twice. It was felt that the two problems could have been related. If the disc drives were slightly out of alignment they could have been ruining the discs. On return to the UK it was found that the problem was probably due to the disc drive running at a varaible speed, so that data was being written and read at different speeds. Osborne, UK offer a service to 'unwrangle' discs with this problem. This analysis would also explain why packages such as 'Disc Doctor' and 'Disk Manager' would not work, since there were no real 'bad sectors' to isolate.

Sometimes when discs were put into a drive the drive door would not close. This problem was a further indication of the need for the machine to be serviced.

Disc capacity is quite limited on the Osborne microcomputer, (about 180K). Although this may be regarded as a disadvantage, on this project it merely meant that less data was lost upon a disc failure! Due to the extremely high disc failure rate the project teams back-up procedure was very stringent, resulting in far less lost data than could have occurred.

The printer had been set up to run via the parallel port (IEEE), on the Osborne. This worked satisfactorily but on purchase of the Trantor hard disc system it was found that this also needed to utilise the IEEE port. Therefore to print a file from hard disc it first had to be dumped on to a floppy disc and the plugs on the IEEE port of the Osborne changed over. Although there was an advantage in having to dump to floppy disc, since backups were then automatically produced, there was the possibility that the IEEE port would become worn.

The major factors concerning problems with the operating system were due to the lack of familiarity with the system, rather than actual system problems. Although CP/M is not the most 'user-freindly' operating system, it is regarded as an industry standard and as such has been thoroughly tried and tested. The project team soon became familiar with the most useful CP/M commands. Certain problems that did arise could only be solved by consulting the main CP/M manuals which are not given to the Osborne owner.

The major computer problems of the project were concerned with the use of FORTRAN 80. Again lack of familiarity with this version of FORTRAN before embarking on the project proved to be costly in time. The manual produced by Microsoft for FORTRAN is of an extremely poor standard. The explanation of how to run a FORTRAN program is very poor. It took several weeks for the team to find a satisfactory routine. A FORTRAN compiler of the size Microsoft produced had to be limited in some areas. The manual should have been more explicit and far more examples were needed. Since there was nobody in Halcrow using the Fortran compiler to the extent required in Bangladesh, the project team had no choice but to go through the procedures using a trial and error approach until they came upon a satisfactory way of running the required routines.

Microsoft BASIC is much simpler and more straightforward to use than FORTRAN. BASIC had only been used in a couple of examples and there were none of the input/output problems of FORTRAN. It was felt that more use could have been made of the BASIC language particularly since there was a BASIC compiler available, which would prove to be considerably faster than the BASIC interpreter.

Other problems that were encountered are included below:-

1. When output from a FORTRAN program was sent to a file on disc, and subsequently printed, the whole file would be printed on one line. To avoid this problem the printer settings had to be altered, which meant altering the microswitchs on the back each time a FORTRAN file was to be printed. By using Wordstar it was obvious that "hard" carriage returns were not present in the output files. (i.e the < symbol was not present at the end of a line). A routine was written to be used from within Wordstar which replaced the "-" symbols at the end of the line with "<", thus providing carriage returns. The file could then be printed without changing the printer switches each time.

2. A Patch program had been sent to the team, but it was not clear what it could do or how to use it.

3. Since there were many discs being lost, a package called 'Disc Doctor' was sent to the team. The package allows bad sectors on a disc to be identified and placed in a file called 'Morgue'. The bad sectors could then always be avoided and the rest of the disc used safely. This package never successfully worked on the failed discs. Presumably

because there were never really any bad sectors, as explained previously, the data had just been written or read at the wrong speed.

4. The Epson printer and the Praxis Typewriter keyboards, (1 and 2) did not completely correspond. This meant that reports set up to be printed on the Epson printer could not always be printed using the Praxis typewriter with the same effect.

5. The normal page break control character in FORTRAN did not appear to work. Therefore, results were often displayed across a page break making it difficult to read.

6.2 Energy Planning Project

The energy planning project is concerned with producing a "Master Plan" study of the energy situation and energy capabilities in Bangladesh. There were three main objectives of the study being carried out :-

1) To provide training and planning procedures for the Bengalis.
2) To provide an 'analytical tool kit', which should be presented in such a way as to allow policy testing on a "what-if" basis.
3) Provide a snapshot of the energy scene.

A similar study had been carried out in 1976 and although useful it had not provided training or a tool kit and for this reason the work needed to be repeated. The study is concerned with energy demands, and energy demand forecasts. Looking at all types of fuels and fuel substitutions where necessary. Many problems were apparent with the study, including data availability, dubious data quality and unknowns including future fuel prices and reserves of natural gas.

The major application of computers on this project was in the role of model building. Most members of the project team were unfamiliar with microcomputers and the project was still in its infancy with much of the equipment still to arrive.

6.2.1 The energy system

Two computer systems were required by this project. The first was to be used primarily as a training aid. The second was to be a powerful machine with the ability to accommodate large matrices. It would have sufficient memory capacity to run large optimisation programs and linear programs inparticular, and perhaps some dynamic programming aspects would be considered.

For training purposes the machine chosen was an Apple IIe with a large amount of add-on hardware and various software packages. A large amount of research had been carried out by Halcrow (Swindon) as to which would be the best computer for the mathematical modelling programs of the project. Eventually one computer was focussed upon. A multi-user minicomputer of 1 Megabyte memory produced by Computer Automation. The computer ran using the UNIX operating system. It was not until final checks were made on the computer prior to ordering that it became obvious that the memory had been partitioned into 128K blocks. Each user could only access 128K words at any time. It was claimed that this amount of memory would be insufficient for the models anticipated on the project. By this time the majority of the project team were meeting in Bangladesh and discussions took place to review the computer requirements. It became apparent that the Bengali counterparts were strongly in favour of IBM microcomputers. This preference must arise from IBM being one of the major dealers in Dacca, the only other being Radio Shack.

The team therefore decided to consider the IBM PC-XT microcomputer, and any other microcomputers with equivalent power, in order to meet the following specifications :-

a. 512K of permenantly addressable memory

b. Operating system with a minimum storage requirement

c. Hard disc facilities

d. Two floppy disc drives

e. Self diagnostics

f. Reliability

g. Available within six weeks of ordering

h. Ease to use for training

i. Linkable to an Olivetti Praxis typewriter (not essential)

j. Should demonstrate that it can run powerful Linear Programming solvers using "Haverley" systems or similar.

6.2.2 Energy system problems

During the first few weeks of the project the Apple was being used in a room without air conditioning. The only problems this had at the time was to make the paper in the printer soggy. However, it was felt that the lack of air conditioning would have a detrimental effect in the long term, and so one was to be fitted as soon as possible. There were considerable problems in loading some software packages, particularly the Apple Graphics package and Multiplan, (an electronic spreadsheet package, implemented using the Z80 board). The problem was intermittent and, without testing equipment it proved difficult to isolate. A detailed account of the problems was sent back to Halcrow, (Swindon) and in due course the Apple agent diagnosed the problem as a faulty chip and a new chip was sent out to Bangladesh. The computer still had the loading problems and eventually it had to be returned to Swindon for repair, whereupon it was found that the mains lead was faulty.

6.2.3 Energy applications

Apart from the large optimisation models that were envisaged, the Project Economist was designing various smaller models based on the data available. The Gas Model discussed in Chapter 7.2 is one of these. The Multiplan package was also being used to record and collate data. It was envisaged that the Apple would also be used to run some type of project management package and the secretaries were to be trained to use the word processing package. The counterparts were given full access to the Apple computer but, even though they had been on the training course, their progress was slow.

6.3 State of Computer Technology in Bangladesh

There are only two major computer agents in Bangladesh (Dhaka), IBM and Radio Shack. Both agents could only offer older machines, and the latest technology was not available. This situation is typical of many underdeveloped countries where the standard of the use of technology is low. Many companies tend to use these areas as a dumping ground for their older equipment.

The availability of computers in Bangladesh was quite low. The main area of use was in foreign donor situations and Bangladesh government agencies. Use in the public sector was quite limited. In 1981 a survey was carried out by USAID in which they provided a report on the then current status of computer use in Bangladesh. The survey points out that Bangladesh entered the computer age as early as 1964. The first computer was an IBM machine installed at the Dacca Atomic Energy Centre. The first commercial computer to be installed was an ICL 1901 at the Janata Bank in 1967. Table 6.1 is from the survey and shows the dependance on IBM equipment. An interesting point to note is that the IBM 4341 which was due for installation in 1981 had not appeared by October 1983.

In 1983 it was apparent that many of the foreign aid agencies were using microcomputers. The Apple II and Apple IIe were the most popular microcomputer. Some had bought the computers and software in Bangkok and Singapore where they can be purchased for a fraction of the retail price in the USA and Europe. Many of the agencies using microcomputers restricted their usage to only their expatriate staff. They found problems in allowing Bengalis to use them. Training the Bengalis proved to be difficult and once they became profficient in using a computer they often moved to foreign parts (eg. Saudi Arabia) to earn more money. This problem was widely experienced.

When asked about support and maintenance of machines, all users had found the Apple completely reliable and had had no problems.

TABLE 6.1 Computer Users in Bangladesh (as of Jan. 1,1981)

ORGANISATION	TYPE OF COMPUTER	YEAR INSTALLED
Adanjee Jute Mills Ltd	IBM 370/115(160K) IBM 1401/16K	1980 1968
Agrani Bank	IBM 1401/16K	1967
Atomic Energy Comission	IBM 1620/64K IBM 4341/L01	1964* 1981**
Bangladesh Bureau of Statistics	IBM 360/30(64K) IBM 4341/K01 IBM System 34(128K)	1973 1981** 1981**
Bangladesh Bank	IBM 370/115(160K)	1980
Bangladesh Meteorological Department	IBM System 34(48K)	1980
Bangladesh University of Enginering & Technology	IBM 370/115(160K)	1979
International center for Diarrhoreal Disease Research	IBM System 34(128K)	1980
Janata Bank	ICL (8K) Central Processor	1967*
Project Implementation	IBM System 34(256K)	1981**
Population Control & Family Planning Division	IBM System 34(64K)	1981**

* Temporarliy out of service
** To be installed

One United Nations Development Planning (UNDP) establishment visited, was using a Tandy system. The system consisted of 1 TRS-80, 2x8.4 Megabyte hard disc drives, 2x8" floppy disc drives, 1 graph plotter and 1 dot matrix printer. An IBM minicomputer was used for data preparation. The 8" discs produced by the IBM could be reformatted for the Tandy using available software. The object of the work was to build up a reliable data bank of information on surface water in Bangladesh. The most interesting aspect of the system was the computer management. The system was kept in its own air conditioned room. Shoes had to be changed before entering the room and the room had limited access. Although it may be felt that this office had taken computer security and management a little far, they could boast that they had suffered no breakdowns, no loss of data, and no failure of discs.

Since the Water project had encouraged the counterparts to use the microcomputers an attempt was made to find their attitudes to the modern technology with which they were confronted. The general reaction was that microcomputers were very useful. They felt that a training course would have been beneficial. Some found that since they were not using the machines regularly they soon forgot what had been previously learnt. All senior staff said that they completely approved of the microcomputers. They stated that they would be used extensively once Halcrow had finished the work and left. This view was contradicted by some of the younger, more enthusiastic, staff who felt that senior staff felt threatened by the machines. The younger staff did not feel that the computers would be implemented at the end of the project.

Overall the Bengalis showed very little enthusiasm for work with microcomputers and this was felt to arise from problems of status and seniority.

6.4 Feasibility of using Microcomputers on Overseas Projects

The feasibility of using microcomputers on overseas projects is extremely difficult to measure in quantitative terms. One of the more obvious ways is to measure the reduction in time and cost by using microcomputers instead of more conventional methods. Since the two variables, time and cost, are inter-dependent it is difficult to isolate them meaningfully, although the former should be easier to measure than the latter. Initially, there is always an increase in cost, due to the purchase of hardware and software packages and the cost of software development. In some projects it may be found that costs are not effectively decreased but there may have been an improvement in the quality of the project work, (perhaps a better design is obtained or a solution closer to the optimum is found) by using the microcomputer. Such improvements are not always feasible or practical by ordinary numerical methods done by hand.

The use of the microcomputer may be regarded as mandatory since the client expects the company to make use of them and such clauses are often specifically mentioned in the terms of reference of a contract. Therefore by not using microcomputers companies will invariably lose overseas work. Often funding agencies see the microcomputer as a tool which will help bring the developing country into the 20th century in terms of technology at a low cost. There is, therefore, much more at stake than merely determining whether using a microcomputer is cost-effective or not, as such equipment is increasingly being seen as a necessary prerequisite by potential clients and funding bodies prior to contract allocation.

In order to investigate whether microcomputers are cost-beneficial a model would have to be developed to measure time and costs whilst using the microcomputer and relate this to the time and cost of the work if it were being carried out by hand. An example of how such models should be set up is presented in the following subsection.

A technique to design a cost benefit model was suggested by L'Aguilar (1984). L'Aguilar examined a microcomputer system in a design office environment. The actual system set-up costs were found, and then the author derived formulae to estimate the profitability of the system. These formulae were based on the amount of time the design team would normally have spent in manual calculations and the manual/computer trade-off. The author decided on the cost-benefit ratio in terms of the cost of design by reducing the time spent in calculations. The procedure put forward was simple and perhaps effective in a design office in the UK. However, when considering the use of microcomputers on overseas projects there are many intangible benefits which must be taken into account.

In order to examine the cost effectiveness of any new technology it is necessary to compare it with the system prior to implementation of that technology. This old/new comparisson is particularly difficult with water resources projects overseas, all of which are significantly different from each other. Therefore such comparisons can only be used as typical representations.

6.4.1 Costs of using a microcomputer

The costs of using a microcomputer on an overseas project are normally contained within the project price and are therefore costs to the client and not to the consultant. Nonetheless, it is still important that costs are clearly identified. Even though these costs are accountable to the client they will have an overall effect on the final project price and therefore must be considered. Four types of cost have been identified: hardware costs; software package costs; program production costs; and manpower costs.

Tables 6.2 and 6.3 identify the typical hardware and software package costs respectively. The former costs include costs incurred in

TABLE 6.2 Hardware Costs for an Overseas Project

TYPE	NOMINAL COST (£) (1984 prices)
Microcomputer	2200
Printer	600
VDU	Incl. in price
Winchester disc	1200
Insurance	@20% of cost
Maintenance	@20% of cost
Power Supply	600
Export Duties	none
Transportation	excess baggage
Sundries e.g discs, tapes, paper	600

TABLE 6.3 Software Package Costs for an Overseas Project

TYPE	NOMINAL COST (£)
COMPILED BASIC	330
FORTRAN	350
Sreadsheet	295
Database	495
Word Processing	295

using and transporting the equipment.

Programming costs are very difficult to evaluate, since there are no definite industrial measures by which programs can be assessed. Organisations have long wanted to accurately estimate programming productivity and program costs. Shwartz (1975) in looking at the problem and practicalities of constructing software, discussed some aides for the costing of software. Schwartz pointed out the lack of accuracy of making estimates but provided a set of guidelines which were useful as a basis for developing a program cost estimator. He stated that the cost of software is most often underestimated by a factor of 2.5. The number of instructions/hour/man being developed for large systems can be as low as 3 and is known to fall to 1 in some cases. For tasks similar to those previously undertaken the cost can be only 10%-30% of the original job. This result shows that production capability does significantly improve when using the same technique or programming similar jobs. All these estimates have to be based on problem complexity, size, hardware, programmer experience, programming language used etc.

Watson and Felix (1977) carried out a considerable amount of research into programming measurement and estimation over several years. Their research included the setting up of a measurements database. The data being obtained from questionnaires which were given to continuing projects at regular intervals. For any completed projects the total number of source lines of code and the number of man-months spent on the software could be found. The database contained a wide variety of projects using many different computer languages and systems. From the database, queries on these specific projects could be answered and analyses carried out. Programming project productivity estimations could be carried out for new and ongoing projects. Productivity was defined as the number of source lines of code per man-month.

Watson and Felix were also able to estimate the effect of certain factors upon productivity and weight those factors accordingly. The resulting productivity model was fairly complex although the authors were quick to point out that it was far from optimal and further work was planned.

Collofello et al (1982) reviewed the types of productivity measures commonly being used. They noted that two major approaches were cost per line of code and number of lines per man-month produced, the latter being more frequently used. Other less known approaches include decomposing the lines of code into operators and operands, and abandoning lines of code completely and concentrating on the actual functions of the program and external user interaction. The authors went on to show the discrepancies apparent in these approaches. Since the difficulty of software writing is based upon the complexity of the problem, it is argued that the number of lines of code is immaterial. It is also noted that the measures do not take into account the maintenance of software, or the quality of the programs being developed. Collofello et al went on to propose a productivity model for program measurement, but the model was only theoretical and needed further development.

It is apparent that there are various approaches and pitfalls in trying to measure programmer productivity. The Watson and Felix approach required a long term effort to design and implement. Collofello et al could only produce a hypothetical approach and Schwartz did not provide enough information on his method for it to be used in this thesis.

In order to provide Halcrow with an idea of program costs to the consultancy a simple program cost model was developed. There are two basic ways to cost a program: the first is to price the program by examining the time to complete the program in question; the second is to put a nominal price on the program according to its worth, which would usually depend upon the application area.

An experiment was conducted to estimate program cost by finding the time for program production and therefore producing the average cost for one line of code. A simple problem, that of finding the day upon which a particular date fell, was chosen. The outline of the problem is given in Appendix F. The problem was considered simple enough for anyone with average ability to tackle, without being too simple to render the experiment unrealistic. A sample of final year and postgraduate civil engineering students were considered most suitable to carry out the programming since they were the closest representation to a civil engineering project team that could be obtained. Each person was given the program and asked to time themselves for program preparation, encoding, loading onto the computer and finally debugging. Firstly, the experiment was tested on three people and any anomilies were eliminated. Eight volunteers were then found to carry out the experiment. The results are given in Table 6.4.

On analysing the programs it was obvious that they were extremely varied and it would be difficult to evaluate a realistic figure for programmer productivity from them. However, the results did show that programming experience, background, familiarity with equipment, ability and familiarity with the language all had to be taken into account. The programs as well as the approaches by the participants themselves were very different. Some were more conscientious about following 'correct' programming procedures, developing algorithms and flowcharts prior to coding, while others went straight into coding without much preparation. The size of the programs also varied, and

TABLE 6.4 Program Cost Experiment Results.

Function	1	2	3	4	5	6	7	8
Reading (%)	4	4	5	11	13	12	.005	.4
Algorithm (%)	12	4	-	-	-	-	.08	-
Write code (%)	12	20	35	44	27	-	24	26
Enter computer (%)	24	20	28	39	40	62.5	48	24
Debug (%)	48	52	32	.05	20	25	16	45
Total time (mins)	120	70	85	90	75	120	63	141
Total no. of lines	60	35	40	42	61	43	115	53
Working properly	Y	N	Y	Y	Y	Y	Y	Y
Familiarity with language	P	AV	G	G	AV	G	VG	P
Familiarity with micro	NONE	AV	G	G	G	VG	AV	G

(Where:- AV = average, G = good, N = no, P = poor, VG = very good, Y = yes).

was reflected in program usability and user friendliness; generally the larger the program the more readable it was (i.e. greater number of documentation statements), and the more user friendly. The variability in these factors described make the cost of programming difficult to ascertain. Productivity levels have been evaluated and are given in Table 6.5. The actual quality of the programs produced cannot be accounted for when costing on a line of code per hour basis. However, it was considered that some breakdown would be useful to Halcrow in order that they should realise the cost of software to them and the loss of revenue by not charging clients. It can be seen from Table 6.5 that the programmers achieved a productivity level of about 30 instructions/hour. (120 lines/hour was regarded as exceptional and not included in the average). Documentation had not been included in these figures and would probably increase the time by 40-50%, therefore bringing the average number of instructions to about 20 instructions/hour.

TABLE 6.5 Programmer Productivity

Programmer	1	2	3	4	5	6	7	8
lines/hr	30	30	28	30	48	21	120	22.5

It must be remembered that this level of production would not be continued for a day or month so the figures cannot be multiplied upwards in a linear manner. They also represent the programming of a simple single purpose program with no interactions with the system, data files etc. Therefore these levels of production must be regarded as a maximum level. Even so they give an idea of the cost of software and indicate the amount that may be being spent. In Halcrow this expenditure is being met by a research and development budget. If some charge were to be made for software development the money could recirculated into the planning and research and development policy of the company.

True manpower costs are just as difficult to quantify, as some are trade-off costs and some, such as engineer training costs, can be regarded as investment costs by the consultancy and consequently cannot be added to the final total as an out and out cost to the project. Where an engineer has not had training there will be less instructions per day generated, and so an extra cost is incurred. For the model being developed in this section manpower costs for the new and old system can be evaluated by examining the size of the project team and the project duration. The total can then be evaluated in terms of man-months and a cost derived from there.

6.4.2 Benefits of using a microcomputer

As with costs, it is important to separate the benefits to the client from the benefits to the consultant. Although the profit criterion is not as important as one would expect in the decision to use a microcomputer it is still important to be able to quantify the financial aspects of the system in order that managememt decisions can be made readily. A method of quantifying the intangible aspects of the system have to be found.

The costs of the new technology will nearly always be higher than the old system, and so the benefits of the new system have to be quantified if cost effectiveness is to be proved. Typical benefits from using a microcomputer on an overseas project are given in Table 6.6 along with the consequences they may have on the project.

Four major benefits can be identified from Table 6.6.

a) The consultancy is more likely to get a contract if microcomputers are used.

b) Savings in cost and project time are made.

c) More reliable results are obtained.

d) Client satisfaction leads to more work for the consultancy.

The benefits listed above will not occur on all projects and some are very difficult to quantify. Benefits (a) and (d) (above) are intangible whilst (b) and (c) can be given values. In order to investigate whether microcomputers are cost effective an actual project is studied in the next subsection.

TABLE 6.6 Benefits in using Microcomputers on Overseas Projects.

CONSEQUENCES	BENEFITS
Process more data	more reliable results
Overseas governments are impressed by the technology	more likely to get the contract
Aid organisations expect to see the latest techniques being used	more likely to get the contract
All data processing can be carried out on-site	saves time and cost
Saves using a base computer or client computer	saves time and cost
Improved security	less susceptible to industrial espionage
Allows more options to be developed and critically examined	more reliable results
Some software can be developed prior to going on-site	saves time and cost
A company using the latest techniques is more likely to get more jobs	more contracts
Project management is made easier leaving the engineer to get on with the real project tasks	saves time and cost
It is the only way some countries can get the new technology and the training needed	more likely to get the contract

6.4.3 A cost benefit analysis

A recent project carried out in the Aguan Valley, Honduras has been examined and analysed. The project involved a two-year master plan study of part of the Aguan Valley and the consultants decided to include a microcomputer as part of the project tender.

The microcomputer system chosen was a Commodore 8096 computer with an 8023 dual disc drive and 8034 printer. The computer was chosen because the consultancy already had such a system in its head office and members of the project team were already familiar with the equipment. A large number of hydraulic and hydrology programs had also been written for the Commodore system by head office personnel.

During the first year of the project no software was actually developed on-site. The software developed in head office was principally used by the hydrologist of the project team. During the second year the microcomputer was used extensively by several members of the team. Additional software was developed mainly using Visicalc, (a spreadsheet package), and Hornet, (a project management package). The amount of data generated at one point in the project was so large that some was taken back to the UK and analysed on two systems there, one of which was rented specifically for that task for one month.

During the second year of the project some hardware faults occurred. Since no back-up facilities were available a second 8096 computer was bought. The failure was eventually traced and the older machine was used as a backup machine from then on.

Not all programs taken from the UK office were charged to the project. Since some had been developed under a research and development budget. Various members of the team used the computers. Team familiarity is shown in Table 6.7.

TABLE 6.7 Project Team Familiarity With Computers.

Team Member	Familiar with computers	Used computers on project
Project Manager	no	no
Hydrologist	yes	yes, extensively
3 Design engineers	1 yes 2 no	all, yes
Economist	no	yes
Agriculturalist	yes	yes
Agric/Economist	yes	yes
2 Surveyors	no	no
Visiting specialists	no	no

The actual use of the computer can be broken down into three main areas:-

i) Engineering design - Using BASIC programs and Visicalc

ii) Project management - Using Hornet

iii) Engineering costing - Using Visicalc

These three areas need to be examined and compared with the same project as if a microcomputer not been used in order to see whether the microcomputer was cost effective. Although a direct comparison is impossible, estimates can be made as to the effect of not using a microcomputer on the project.

The duration of the project is always fixed by the consultant on making a tender. This project was for two years. The project consisted of a total input of 200 man-months of which it has been estimated that 100 man-months were spent using the microcomputer. Since the project was a feasibility study there were many alternatives to appraise. The

Aguan Valley was sub-divided into several areas, each with their own alternatives to be examined. Each area had to fit in with its neighbour, and so the number of combinations generated was extremely large. Due to the processing power of the microcomputer, each alternative could be analysed and assessed within the projects time scale. If the microcomputer had not been used the team would have had to have chosen intuitively a subset of the alternatives to examine fully by hand. A full hand analysis of all alternatives would have proved too time consuming, as is probabaly true of all such project comparisons. The work on the microcomputer could not have been feasibly carried out by hand, and other less sophisticated techniques would have been found to ensure a good set of results. In some cases the work could not have been done at all without a microcomputer. In the project being reviewed the client asked for a network analysis of the project to be drawn up and continually updated. This task would have proved impossible to do manually, but a project management package, (Hornet) was purchased to carry out the task.

The total cost of the project without a microcomputer would have been 200 man-months at $10,000 per man-month, equallying $2 million, but the results would have been less accurate and less sensitive. To achieve the same results in engineering design and engineering costing it was estimated that an extra 15 to 25 man-months would have been required. The network analysis requested by the client could not have been done. Therefore to gain results close to those when using a microcomputer would have cost at least $150,000 more.

The overall cost of including a microcomputer are shown in Tables 6.8 and 6.9. The total expenditure was £4775.

TABLE 6.8 Hardware Costs for the Aguan Valley Project.

Hardware	Cost
Computer System	3500
Transportation	25 (excess baggage)
Insurance	-
Sundries	750
Voltage regulator	250
Hire of second system	250

TABLE 6.9 Software Costs for the Aguan Valley Project.

SOFTWARE	COST
Visicalc	195
Hornet	1500
BASIC	free with system

From the figures produced, the use of the microcomputer system has produced a net saving of approximately $142,000 to achieve relatively similar results. This figure is extremely high but software development was not taken into consideration and would have cost considerably more than the hardware. In this case the software developed for the project was not charged to the client. Many of the benefits of each option cannot have values put upon them, and so a table of comparitive benefits has been produced, (Table 6.10).

TABLE 6.10 Comparitive Benefits of using a Microcomputer

USING A MICROCOMPUTER	NOT USING A MICROCOMPUTER
More alternatives analysed	Standard engineering procedures familiar to project team
Improved results	Results
Improved sensitivity analysis	Standard analysis
Improved consultancy credibility and integrity	Consultancy reputation for standard methods
Network analysis provided	No network analysis
More extensive data set was provided for examination by computational hydraulis model	Standard data set analysed
Effectively trained some counterpart staff in the use of higher technology	No training of counter-parts in modern technology

It can be seen from Table 6.10 that the benefits of using a microcomputer strongly outweigh those of not using one. The cost benefit analysis of this project really centres on the provision of improved results. The cost of those results being the cost of the hardware and software purchased for the project. Further benefits could possibly have been gained if the project manager had used the microcomputer for some of his adminstrative and managerial work, thereby releasing some of his time for more important project problems that may have arose.

The computer equipment was continued to be used by the client and has now been transferred to another project in the same area.

6.5 Impact of Microcomputers on Project Work on Overseas Projects

Halcrow have put more emphasis on, and become more commited to, the use of the microcomputer on overseas projects. Over the past two years the number of microcomputers being bought or leased for overseas project work has increased dramatically. Since many funding agencies are now expecting the use of computers on-site, whilst still keeping projects to a minimum cost, the microcomputer is becoming a more feasible option. Over the past year many microcomputers have appeared on the market, with increasing speed and memory size, enabling engineers to make more use of them.

The following recommendations have been derived from the case studies:-

1. COMMUNICATION - Microcomputers will only become cost-effective if their use is carefully monitored. Software and ideas should be passed between various project teams, this will save time and costs of duplicating work.

2. FLEXIBILITY - Project teams should remain as flexible as possible in their attitude to software and hardware. Software should be chosen to suit the project members and clients as well as the project work itself. Hardware should only be bought once the software applications have been identified.

3. TRAINING - Project teams must have some training on the microcomputers prior to their use overseas. There should be a provision in the terms of reference to include a training course for the counterparts/clients. Training is particularly important if the machines are to remain overseas once the consultants have finished their project.

4. PROBLEMS - Problems due to adverse conditions should be anticipated. These include humidity, heat, voltage irregularities and power failures.

5. SUPPORT & MAINTENANCE - An agent in the country would be a definite advantage. If not, the machine chosen should be the same as a machine in head office whenever possible. This should enable queries to be

dealt with quickly. If a machine were to breakdown in an emergency situation it could be replaced with one from head office, saving considerable time in repair turnaround.

6. TESTING - All equipment should be unboxed and thoroughly tested before being sent abroad. If possible it should be tested by a member of the project team and any queries can then be dealt with directly.

7. FIRMWARE - Discs should be of the best quality and the backing up procedure should be stringent. Thus allowing minimal loss of software and data.

The cost of software will always be far higher than the cost of hardware and it is unlikely that sofware development will decrease in cost in the forseeable future. Therefore Halcrow will have to ensure that any software developed outside a project but used overseas is charged to the client.

The microcomputer is having an impact on overseas civil engineering projects and the impact will become larger as hardware costs fall and microcomputers become more powerful. If Halcrow are to gain the benefits of using micrcomputers they need to monitor the use of computers on projects and learn from their experiences.

CHAPTER SEVEN APPLICATIONS ON THE MICROCOMPUTER

In order to investigate the feasibility of using the microcomputer on overseas projects, two different applications were tackled. The first application involved the use of dynamic programming to solve a single site reservoir optimisation problem. Secondly, a simulation program was developed to examine the Bangladesh gas supply system and its development. Halcrow were particularly interested in the development of systems analysis techniques as an aid to project feasibility tests and in the ability to develop effective pre-screening models which could be easily produced and used on overseas sites. Although there are various linear and non-linear programming methods which could have been tackled, it was decided to design a dynamic programming model since it represents a general approach usually requiring large amounts of run-time and memory.

The Gas simulation model was designed on-site to give the project economist in Bangladesh some idea of the effects of varying investment in the gas grid system.

7.1 Dynamic Programming

Dynamic programming is a multi-stage decision process in which a system is broken down into discrete stages and the optimal path is obtained by following through the problem stage by stage. Dynamic programming requires large amounts of computer run time and computer memory and would therefore exploit the microcomputer to the full.

7.1.1 Dynamic programming in water resources

The planning of water resources systems has become an extremely complex and costly excercise over the past few years. The greatest problem in planning a water resources system being that the resource is often not available in the quantities and qualities required at the time and place it is required. Water is a precious commodity, particularly in many overseas development areas and, it is no longer sufficient to plan a water resources project as a single entity. It has long been recognised that there must be some thought of combining the project with existing systems or planning for the project to expand into a larger system itself, i.e. the system should be multi-purpose rather than single purpose whenever possible. Obviously, when looking at multi-purpose systems, the permutations of planning alternatives making up the whole system can be large and it is difficult to find a set of alternatives which will maximise the objectives of the project.

Johnson (1972) attempts to calculate the amount of times systems analysis techniques are being used in the planning of water resources systems in the U.S. He defines systems analysis to mean computer simulation models to optimise a system and mathematical models that use optimisation techniques such as linear, non-linear and dynamic programming in the analysis of water resources systems. His work was based on information collected through questionnaires, interviews and a literature review. The survey was based on the questionnaires, the interviews used to clarify answers where needed. The literature review was used to denote to what extent the use of systems analysis in the real world was being reported in the literature. Johnson explains that systems analysis is not necessarily used very often and in many cases will not work. He points out that in a practitioners world systems analysis is often very difficult to apply. Although evidence was produced showing systems analysis to be a powerful tool the practitioner still finds difficult to decide when systems analysis can be used in planning and design studies and have a reasonable assurance that the results will be as good, if not better than those derived from traditional practices. The author attributes this indecision to two major factors :- firstly the literature is saturated with hypothetical problems, more real world applications are needed. Secondly, the need for a review of in-house research with more emphasis on systems analysis techniques. Basically, Johnson sees the overall problem not as a lack in the state of the technology but rather as a lack in understanding and communication between engineers and planners.

Each water resources system has its own objectives which the development is intended to meet. Water resources systems are particularly difficult to deal with since there are many objectives to which an actual price or quantity is difficult to fix. In addition the quantitative functional realtionships are often in an incompatible form and do not meet the conditions necessary for the standard formulation of mathematical techniques. When looking at a system with numerous alternatives and numerous stages the computational task can be extremely tedious. Several widely used methods exist which can result in a major reduction in computational effort, these include differential calculus, gradient search procedures, linear programming, dynamic programming and simulation (Hall and Dracup, 1970).

Butcher (1968) reviewed various of the mathematical modelling methods capable of determining the optimal allocation of water. His review included linear programing, stochastic linear programming, dynamic programming and stochastic dynamic programming. His conclusions state that for the optimum operation of a single reservior the dynamic programming method is preferred since it is simpler, more direct and involves far less computation than linear programming alternatives. However, even by using deterministic dynamic programming where multi-reservoir systems are concerned the problem becomes unmanageable. Butcher advises that the system should be split into discrete units, each unit is optimised using dynamic programming and the optimisation of the overall problem can then be solved using linear programming on the separate solutions acquired, this technique was first approached by Hall (1964). Butcher eliminates simulation as a "what-if" process, only allowing certain operating rules to be tested under certain conditions.

Dynamic programming is an optimisation technique developed by Bellman (1957) to deal with sequential decision processes. Dynamic programming is based upon the mathematical notation of recursion. A multi-stage problem can be broken down into a set of smaller problems and the results from these smaller problems can be combined to obtain to solution to the whole. Bellman based his theory upon the principle of optimality,

"an optimal policy will have the property that whatever the initial state and initial decision will be, the remaining decisions must constitute an optimal policy with regard to the state resulting from the first decision".

Dynamic programming is a useful technique in the preliminary screening of a number of alternatives in a systems context.

In multi-stage decision processes one seeks a sequence of decisions which optimise the objective function. The stages at which the decisions are made need not be of equal length. Nemhauser (1966) described dynamic programming as an approach to optimisation, since it refers to a computational technique rather than a rigid form of non-linear, non-convex, discontinuos objectives whereas other techniques cannot. Since dynamic programming deals with multi-stage problems it is applicable to those problems in which time plays an important role and in which the sequence of decision is vital, thereby making the method eminently suitable for water resources problems.

Buras (1966) in a review of dynamic programming in water resources development, outlines the rationale for the use of dynamic programming. Buras points out that although the principle of optimality has an attractive simplicity, it should be remembered that not all multistage decision processes can be solved by dynamic programming. Buras goes on to identify several areas of water resources planning where dynamic programming would be applicable. These include problems of water storage, conjunctive use of groundwater and surface water systems and hydroelectric power production.

Schweig (1972) demonstrated the practical application of dynamic programming for determining the optimal control rules for a water storage system. He takes a hypothetical system of a surface reservoir and an underground aquifer which have to satisfy the demand rates of some residual area. The aquifer is considered large enough to avert any danger of emptying, but the output is limited. Costs for treating and pumping the water are given as are the inflow data to the surface reservoir. Calculations are simplified by dealing with four seasons rather than twelve months. The inflows into the reservoir have known probability distributions for each season, given by three points on a supposed distribution curve. The objective being to establish a policy of optimal operations for each season, subject to cost and inflows, whilst ensuring that supply will meet demand. Schweig follows through the steps of the dynamic programming method clearly and concisely, the final product of the optimisation process being a set of tables, one for each stage, showing the optimal conditions of releases and pumping rates in each of the possible states of storage. Schweig goes on to discuss a "Water Research Association" optimisation programme using dynamic programming, examining another hypothetical system. He concludes that dynamic programming followed by a suitable processing of the results allows the water resourcist or engineer to obtain the optimal estimate of costs, spills and shortages to be expected from an optimal operation of the system in question.

Since dynamic programming is an approach to optimisation several authors have demonstrated varying alternatives of the technique in the optimisation of reservoir systems. Gal (1979) uses "the parameter iteration" method to derive an approximate solution to dynamic programming. Hall et al (1968) suggest that a multi- reservoir system, each reservoir on a separate stream, can be analysed by employing dynamic programming for each individual unit to give a set of restricted optimal policies. These policies can then be used recursively with a linear programming procedure to provide the optimal overall policy of the total system. Heidari et al (1971) put forward the discrete differential dynamic programming technique, an itterative technique in which the dynamic programming algorithm is used to search for an improved trajectory amongst other discrete states around the trial trajectory. These variations fall into two broad catagories: those attempting to improve the model in order that it approaches a more realsitic version of the real world model e.g.(Buras,1966); and those which are concerned with reducing computer requirements of the dynamic programming technique, eg Heidari et al (1971).

One of the disadvantages of dynamic programming is that it is expensive in computer memory and time. Computer requirements increase as the dimensionality of the problem increases. Chow et al (1975) attempted to evaluate the time and memory requirements for a given dynamic programming problem. They investigated the trade-offs between using high speed core memory and slow speed peripheral memory for dynamic programming applications. Three areas of storage equipment were identified: machine memory, which will remain almost constant throughout the program run; data storage and code storage which can be supplemented by the use of slow speed peripherals.

7.1.2 Problem statement

The determination of general operating rules for a single reservoir using deterministic dynamic programming is investigated in the following section. Deterministic dynamic programming allows the control of a system which is dependent upon known values. The reservoir capacity is known and a sequence of historical flows are used. System performance has to be measured against a loss or benefit function, the objective function.

The reservoir was divided into a number of ,(N), states and the optimisation was to be run over M stages of one month duration, (where M and N are to be input by the user). Demands on water are known to exist downstream of the reservoir, these demands include compensatory releases and irrigation requirements. The system was costed on a penalty cost system for non-ideal conditions, benefits for near ideal conditions are rewarded by negative costs. These costs are based on reservoir storage, releases and the meeting of demands such as flood protection downstream, irrigation, etc.

The reservoir model is based on the continuity equations :-

$$S_t = S_{t-1} + I_t - R_t \qquad \text{-----} \ (7.1)$$

where:- S= storage
I= inflow
R= release
t=time step, 1,2,3,4----T

The overall problem is to operate a single reservoir for T time periods:-

$$\min [\ C_t, d(S_t R_t)] \qquad \text{----} \ (7.2)$$

where:- C= cost
d= decision

subject to the following constraints :-

$$S_t >= S_t^{min} \text{ ---- } (7.3)$$

$$S_t <= S_t^{max} \text{ ---- } (7.4)$$

$$R_t >= R_t^{min} \text{ ---- } (7.5)$$

where :-

S_t^{min} = minimum allowable storage

S_t^{max} = maximum allowable storage

R_t^{min} = minimum possible release (=0)

The reservoir model is solved by dynamic programming using the following recursive equation.

$$F_t(S_t) = \min \; C_t d(S_t,R_t) + F_{t-1}(S_{t-1}) \quad \text{---- } (7.6)$$

where:- $F_t(S_t)$ = total cost of system to time t

F_{t-1} = cost of system until one previous period (t-1)

$C(S_t,R_t)$ = cost of release at time t

Since the microcomputer was to be used to program the model it was desirable to keep the program and data content to a minimum, at the same time a degree of general purposeness was sought. The method developed for the example described here was based upon a highly modular program with the use of data 'look up tables', which are formed prior to the program run. These tables are used to provide the dynamic program with pre-processed information at run-time, enabling the program to make policy decisions quickly and easily. The use of look-up tables also enhances the flexibility of the main dynamic program.

7.1.3 <u>Dynamic programming computer model</u>

The suite of programs developed in this excercise were used to model a hypothetical problem. The example served to show, both, the feasibility of dynamic programming on a microcomputer and the limitations to be expected. The computer model is based on a suite of programs constructed in a modular and flexible manner in order to enable the user to make changes to the program with the minimum of effort. The model incorporated simple operating rules which can be adapted to suit any similar system being examined. The development of the structure of programs in Figure 7.1 allows the user to change or elaborate policies without having to make major changes to the main dynamic programming algorithm. All programs are of a modular structure, modules are easily replaced or added, therefore giving maximum system flexibility.

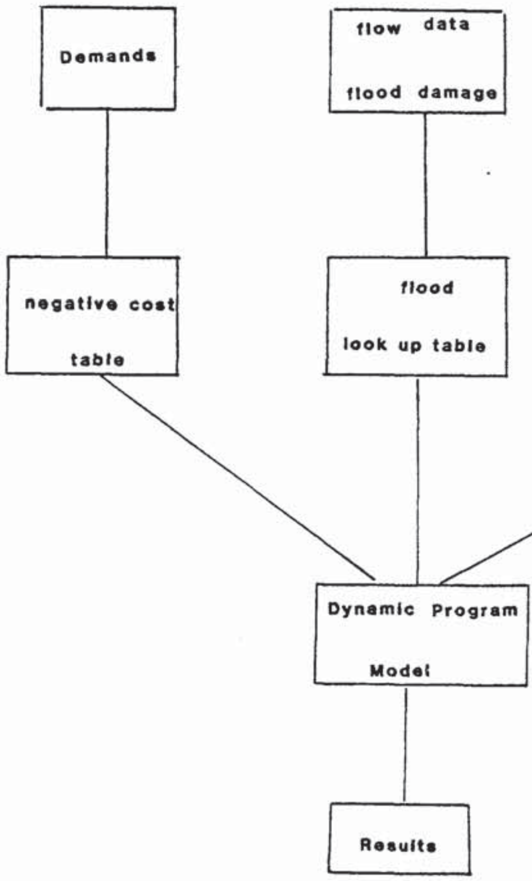


FIGURE 7.1 Interaction of the Suite of Programs.

The example tackled was that of a river system as shown in Figure 7.2. The inflow to the reservoir and the lateral inflow are known. The objective was to provide optimum operating rules for the reservoir such that the area below the reservoir receives maximum benefits, i.e. minimum flooding and droughts.

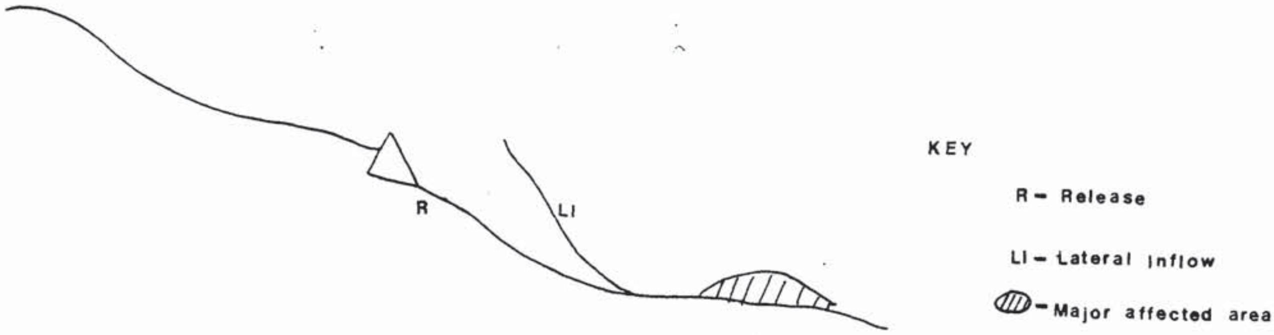


FIGURE 7.2 River System Being Modelled by Dynamic Programming.

Three look-up tables were formed : the flood, irrigation and benefit look-up tables.

The flood look-up table was designed to provide the expected cost of a particular flow made up of the release from the reservoir and the lateral inflow. From several years historic data the probability of a lateral flow occuring during a particular month were found. Discharge/damage curves were then derived for the area under examination and from these the cost of a particular flow occuring could be evaluated. The probability of flow was then multiplied by the expected cost of flow to give the expected cost of flow during a particular month, forming the flood look-up table. The whole process is summarised in Figure 7.3.

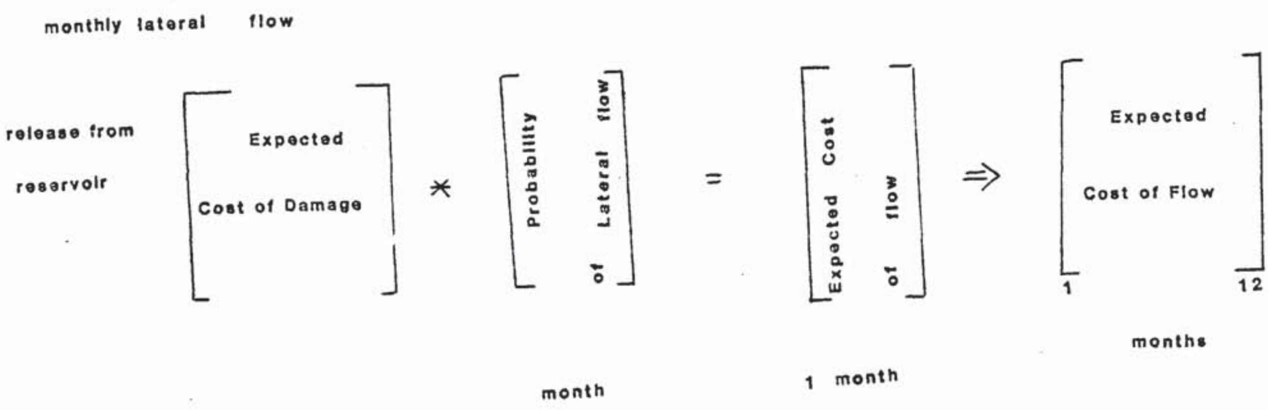


FIGURE 7.3 Forming the Flood Look-Up Table.

The irrigation look-up table was constructed using similar principles as those developed for the flood look-up table. Discharge/crop damage curves were set up for the lack of irrigation water and again a matrix of expected costs of flow were found. The values found were multiplied by the probability of lateral flow to give the irrigation look-up table. Since the purpose of the model being developed in this section is purely demonstrative in the use of microcomputers the detail required of a real system has not been included. The irrigation of a crop is not a simple crop/water relationship, factors such as soil type, soil depth, irrigation efficiency, evapotranspiration, water uptake, rainfall and relative crop yield have to be taken into consideration and a complex relationship is set up. Readers are referred to such literature as Smidcht and Plate (1983) and Hiessel and Plate (1983) if they wish to develop a realistic irrigation routine.

The tables described so far have been formed to provide penalty costs since the results of the moves they produce are non-ideal. However, the case may arise where penalty costs are not applicable and the most ideal solution is required, in that situation a benefits table has to be consulted. The benefits table gives negative costs for the closest to ideal solutions. The benefits table has been constructed in a similar way to the flood and irrigation tables.

The look-up tables were formed by interactive programs within the suite and are stored on disc. On running the main dynamic program, the look-up tables and system data file are read in. The system data file contains such information as the reservoir capacity, compensation releases, compulsory releases etc. The reservoir inflow data is also read in at this point. The user is asked to provide the following parameters:-

1) number of years to model

2) the number of states in the reservoir

3) the number of decisions to examine

The user can then vary these parameters with each run if he so chooses, providing an easy 'what if' capability.

With all the data read in the program proceeds for N states over M stages. The main program consists of four principle subroutines:-

1) Decision Subroutine

2) Release Subroutine

3) Cost Subroutine

4) Optimise Subroutine

Secondary subroutines such as read and print routines are also included within the main program.

The decision subroutine implements the decision parameter given by the user at the begining of the program run. In this example a simple decision policy has been adopted, of allowing the reservoir to remain in its present state or to move a permissible number of states, up or down, from its present state. The permissible number of states is determined by the user and input as the decision parameter. The states to which the present state can move are stored in the decision array and control passed to the release routine.

The release subroutine is based upon the continuity equation given in equation 7.1. Releases are evaluated for the movement from the present state to all the states given in the decision array. The releases corresponding to the decisions are stored in the release array and control is passed onto the cost subroutine. Any negative releases evaluated are not stored and that corresponding decision is removed from the decision array. Spills are also noted in the release subroutine and stored for costing.

The cost subroutine is designed to find the cost of making each release, and consequently the cost to the end state. The costs are stored in the look-up tables. The cost routine decides which look-up table to investigate according to the magnitude of the release; there are also clauses in the routine to deal with spills and the possibility of not meeting compensatory releases. The costs for the movement from the present state to the end states are stored in a cost array.

The optimise subroutine chooses the optimal path, in this example based on cost, from the present state to the end state and stores it in the overall results array.

Control is then passed back to the main routine which chooses the next state and the procedure is carried out again. When all states for that stage are evaluated results are printed on the screen or line printer and the next stage is begun.

The flowcharts for all the programs used in the dynamic programming suite are given in Appendix E. The dynamic programming program suite was written in Applesoft Basic and microcosoft FORTRAN and the results noted.

7.1.4 Results of the Dynamic Programming Model

The actual data used was taken from historical flows at Lake Vyrnwy, however the problem itself was completely hypothetical. Typical results from the model are given in Table 7.1. The table is constructed such that each row represents the optimal path moving from the state in the first element to the end. i.e. row 1 gives the optimal path for the reservoir from January to December if the reservoir is in state 1 in January. The cost table is given alongside. This example was run for 12 stages, (1 year), and the reservoir was divided into 10 states and the decision parameter equalled 3, i.e. the reservoir could move up to 3 states away from its present state.

TABLE 7.1 Typical Dynamic Program Results

month / state	1	2	3	4	5	6	7	8	9	10	11	12	cost
1	1	2	2	2	2	1	1	1	2	2	2	2	358.37
2	2	2	3	3	3	2	1	1	2	2	2	2	655.48
3	3	3	4	4	4	3	2	1	2	2	2	2	1050.22
4	4	4	4	4	4	3	2	1	2	2	2	2	1448.48
5	5	5	5	5	5	4	3	2	3	2	2	2	1948.48
6	6	6	6	6	6	5	4	3	3	2	2	2	2649.35
7	7	7	7	7	7	6	5	4	5	5	2	2	3509.47
8	8	8	8	8	8	7	6	5	6	5	2	2	4009
9	9	9	9	9	9	8	6	3	2	2	2	2	4575.02
10	10	10	10	9	9	8	7	6	3	2	2	2	5436.87

The program was extremely simplified since the object of the excercise was not to model a real world system but to demonstrate the worth of the microcomputer in carrying out such tasks. The use of the look-up tables considerably reduced the complexity of the main program, allowing it to run with the minimum of computer effort and therefore speeding up the whole process. The look-up tables were an essential part of the model. If the tables had been eliminated, and the majority of calculations carried out in main program, the limited amount of memory and limited speed of the 8 bit machine being used would have made the model difficult to develop and slow to run.

Figure 7.4 relates the effects of changing the number of decision variables, number of states and number of stages with computer run-time. When the number of states was low an increase in the number of decision variables had little effect. As the number of states was increased an increase in number of decision variables had more effect. This was due to the state boundaries being more critical when reservoir states are small, and therefore the decision variables (i.e. the releases) having greater effect over more than one state boundary. The cost results in Table 7.1 show there was a bias towards flood alleviation in this example, this accounts for the cost increase down the table.

Stages	States	No.of Decision Variables	Time (minutes)
1	10	3	5
1	10	5	6
1	20	3	12
1	20	5	13
1	20	7	15
2	10	3	10
2	10	5	12
2	20	3	16
2	20	5	24
2	20	7	29

FIGURE 7.4 Effect on Run-Time by Varying Number of Stages, States and Decision Parameters.

It was estimated that such a model would take a civil engineer approximately one month to complete. This figure was based on a suite of programs of 500 lines of code. In chapter 6 programmer productivity was given as 20 lines/hour for a simple problem. Since the dynamic progamming problem would be more complicated the number of lines per hour has been halved. Therefore, at 10 lines per hour there would be 50 hours programming plus 50 hours documentation. (100 hours is equivalent to one man-month). The estimate would be affected by the amount of experience the engineer has in using dynamic programming, in programming microcomputers and the complexity of the system.

7.2 Gas Supply Simulation Model

Bangladesh has a sufficient amount of gas to supply a considerable area. Figure 7.5 shows the proposed gas grid system, the main problem being that all gas fields are in the east of Bangladesh. In order to supply gas to the west a river crossing has to be undertaken, this crossing is proposed between nodes 52 and 53. The following program was developed in order to find the most beneficial plan to build the grid system. The program is written in Apple BASIC.

7.2.1 Gas Computer Model

From the proposed grid the computer program can work out which legs can be built within a particular investment. Legs (pipes) can only be built from active nodes (i.e. nodes at which gas is already present), or by continuing from legs which have been built within that period. Several combinations of legs within a price range often evolve from one investment cost. A cost benefit analysis is then carried out on each set of combinations and the best plan chosen, the next years' investment can then be taken and so the grid is seen to develop.

The program is based on a set of subroutines, the user has to input the number of years the program should simulate and the investment costs for each year, the expected interest rate and the demand growth rate.

The first subroutine determines whether a leg can be built within the investment cost for that year. All leg information is stored in NODARY.

The connections subroutine finds all the allowable combinations of the the legs in NODARY which are equal to or less than the investment. This is a complex routine which works on the principle of finding all

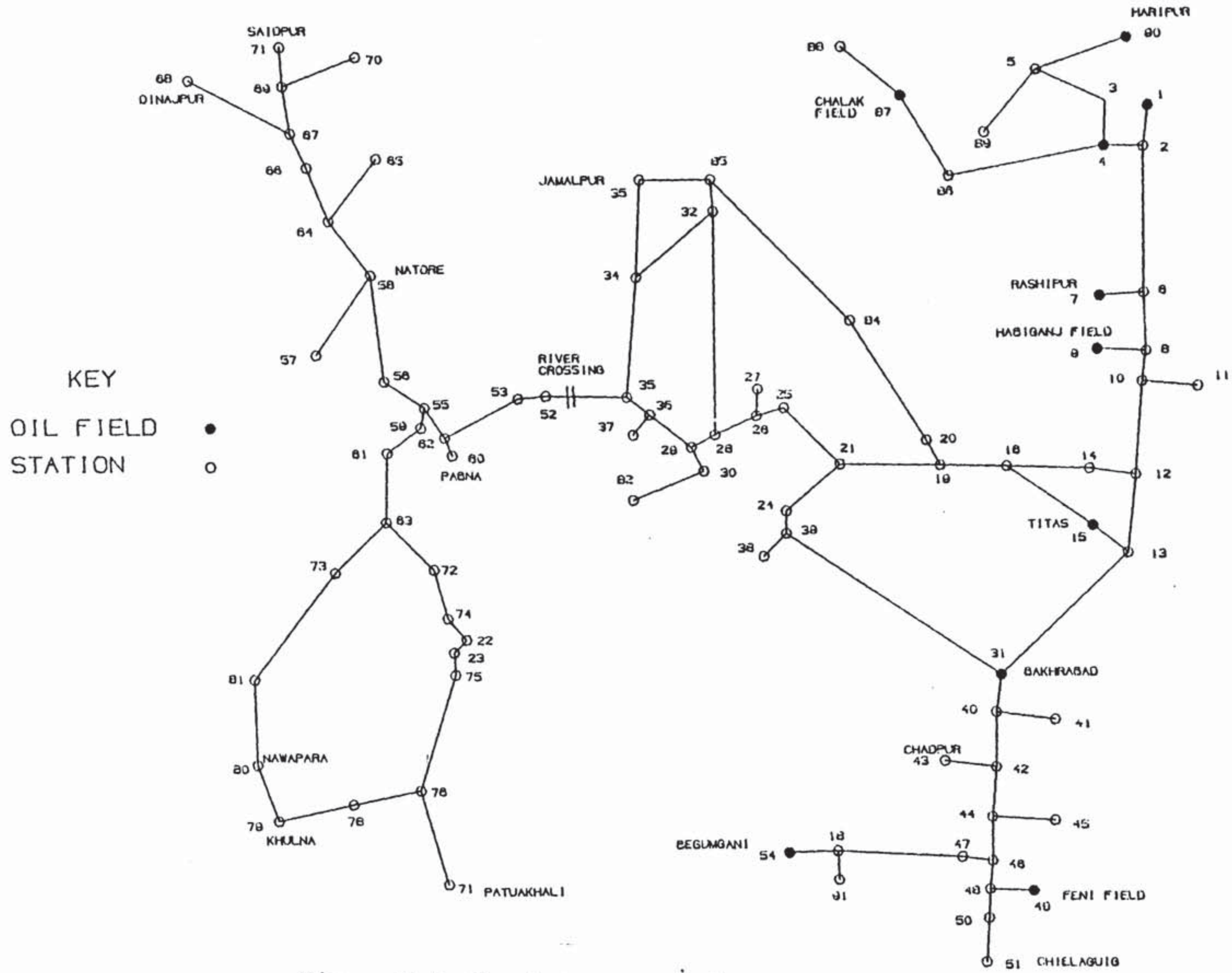


Figure 7.5 Bangladesh Gas Grid System

single combinations (single legs), then double combinations, then triple and so on. Redundancy is eliminated wherever possible.

When all combinations have been found the demands at each node within the combinations are found, these are added to give the total demand for each combination. The following demand equation is used, (Prior,1983):-

$$D_i = D_0(D+C)(1+r_d)^t(1-E)^{-t-t^o} + D(F) + D(P) + D(I)$$

where :- D(D+C)= domestic + commercial demands
D(F)= fertiliser plant demands
D(P)= power plant demands
D(I)= industrial demands.
r_d= growth rate
t=year
t^o=base year

The benefits of building each leg are also found and a cost/benefit analysis value is found for each combination.

$$BENEFIT_i = (O^t - G^t)D_i{}^t(1/1+i)^{t-t^o}$$

where :- O^t= function of oil
G^t= function of gas
i= interest rate
t=year
t^0=base year

The combinations are then sorted on the cost benefit value and the best plan for that year is chosen. The result for each stage (year), will be displayed. With the legs of that stage being treated as built the relevant arrays have to be changed (USER and LEG) to indicate that those nodes are now active. The program then picks up the next years investment and goes through the stage process again.

The routine to choose all possible sets of combinations to build is quite complex and takes a considerable time to run. A summary of results can be printed out if the user wants them.

7.2.2 Results of simulation

Typical results for a 2 year simulation with a growth rate of 0.3 and interest rate of 0.7 are given below :-

Investment Year 1 - 200,000

Investment Year 2 - 400,000

	Pipes built	Total cost
Year 1		
	49 - 48	
	31 - 40	
	40 - 41	183,650
Year 2	41 - 42	
	42 - 44	
	44 - 45	
	15 - 13	395,200

7.3 Conclusions and Feasibility of Using Microcomputers

Both the dynamic programming and gas simulation models were developed to show the feasibility of using microcomputers for non-trivial problems. An in-depth study of the modelling techniques used is outside the scope of this thesis. However, an evaluation of the worth of the models developed can be made.

Both applications showed that with a thorough understanding of the problem and some knowledge of a programming language the microcomputer can be easily implemented. In the dynamic programming application the use of look-up tables was an important feature. Any changes or additions to the model could be made externally, therefore reducing the complexity of the main progam. Since the look-up tables were formed prior to the main program run, the dynamic programs run time was also considerably reduced. The two most critical parameters in the model were the decision variable and the number of states. These had an increasing effect on the amount of memory required and the program run-time as they were increased.

If the model was to be used in a real situation it should be made stochastic, not deterministic. The irrigation routine should be run stochastically, on a daily or five day basis since crop factors are extremely sensitive within short time periods. When the results from the dynamic program are obtained they should be fed into a simulation model in order to evaluate the proposed operating policies, and thence determine the most appropriate irrigation area.

The gas simulation model showed that a small complex simulation program could be developed. In this instance the time factor was more crucial than the memory. However, there is no reason why such a program could not be left running overnight and its output sent to the line printer.

These examples have shown that a problems complexity is not, on its own, a factor to be considered when contemplating a microcomputer orientated solution. The two factors which are dominant are seen to be the amount of memory used and the length of time the program has to run before a solution is reached. The acceptable limits on these two factors are application dependent and will vary according to the individual users requirements. Both memory and run time are factors that are influenced by the choice of make of microcomputer and the technology used in its construction. It can be expected that these facilities, offered by microcomputers, will change as technology proceeds. Such changes in microcomputer technology will be discussed further in Chapter 8.

CHAPTER EIGHT TRENDS AND FORECASTS

The following chapter examines trends in the microcomputer industry (hardware and software), the possible effects they will have on a civil engineering consultancy, such as Halcrow, and the effects on the way in which overseas projects are exected. A forecast of future trends over the next five years is included.

Wise et al (1980) state that the purpose of technological forecasting is to anticipate rapid technological changes and to act accordingly, instead of waiting for the changes to occur before reacting. The basis for forecasts presented in this chapter includes the literature referenced and the expertise gained during the course of the research (1981-1984).

Predicting new technologies which will be developed in the future is very difficult using quantitative forecasting because of the nature of the development of the microcomputer industry. The use of historic data can indicate the trends in existing technology but often there is not enough relevant data and therefore qualitative (technological), forecasting has to be adopted. Qualitative methods of forecasting often do not provide a single answer, but rather an indication towards future technology.

8.1 Hardware Trends

Table 8.1 was taken from Shelley (1981) and gives an outline of computer development over the past 40 years. Fifth generation computers have been added to the table by the author and will be assessed later in the chapter.

TABLE 8.1 Generations of the Computer.

GENERATION	ELECTRONIC COMPONENT	ADVANTAGES	DISADVANTAGES
1st generation 1940-1952	Vacuum Tubes	Vacuum tubes were the only electronic, components available	large size. generated large. amounts of heat. ac required. unreliable. constant maintenance. e.g EDSAC
2nd generation 1952-1964	Transistors	smaller size less heat generated. faster/more reliable.	a/c required maintenance. e.g IBM 1401
3rd generation 1964-1971	Integrated Circuits	even smaller size. even less heat generated. less power reqd. more reliable/faster. sophisticsted op. systems + languages	Initially manufacturer problems e.g ICL 1900
4th generation 1971-1984	Large Scale Integrated Circuits	no a/c required minimal maintenance higher component density. cheapest.	less powerful than mainframes
5th generation 1984-	Very Large Scale Integrated	higher component density expert systems, networking faster/more powerful	need more memory and more sophisticated operating systems

The major reason for such a rapid growth in microcomputer technology has been the development of chip technology. Figure 8.1 examines the increasing trend in the number of components per chip over time, (Wise et al,1980). In order to achieve such an increase in the number of components on a chip the average area occupied by each component was being reduced at a rate of approximately 30% annually until 1980. This increase cannot be expected to continue at the rate particularly since optical lithography (the technology required to form the chips) has approached its limits and X-ray lithography is now used with most chips now actually being designed by computer.

The 16 bit chip has become the most important CPU chip with three major 16 bit chips competing for the market lead in their use in microcomputer systems,(Z8000, MC68000 and 8086). The Motorola MC68000 appears to be the major contender at the present time. 32 bit CPU chips, such as the Motorola 68020, will become widely available in the next two years, (1984-1986), and will be used to produce extremely powerful systems, threatening the power of many of the minicomputers of today. This increased power of 16 and 32 bit chips has many implications for engineering consultancies, since much of their work is highly technical and requires such facilities. It may be advantageous for Halcrow to concentrate their research on systems utilising 16 and 32 bit chips rather than spending large amounts of time and money on developing software for 8 bit systems, and then have to restyle and redevelop for the advancing technology. Alternatively, they may find it more cost effective to write modular software, therefore making it more portable to alternative machines.

An important trend in the development of microcomputer systems has been the increase in memory capacity. The capacity of memory chips has increased continually over the last decade, the 1Mbit memory chip was recently announced (1984) and the 4Mbit chip is expected within the next year or so (1985). Tables 8.2 and 8.3 show the increased development of memory and the decrease in relative cost since 1978. RAM costs are expected to continue to decrease by about 20% per year for the next three years at least, (until 1987). Memory capability is an important aspect to Halcrow, with many of their engineering programs requiring large amounts of memory it was previously impossible to put them onto a microcomputer. It can be expected that

TABLE 8.2 Trends in Cost of Dynamic RAMs.

YEAR	SIZE	COST $	SPEED (ns)	DISCOUNT TO 1978 @ 10%
78	16K*1	9.95	350	9.95
79	16K*1	8.5	200	7.73
80	16K*1	7.95	200	6.6
81	64K*1 16K*1	19.95 1.80	200 200	14.95 1.35
82	16K*1 64K*1	2.0 6.25	200 200	1.37 4.27
83	16K*1 64K*1 64K*1	1.49 5.9 6.9	200 200 150	0.92 3.66 4.28
84	16K*1 64K*1	1.69 5.95	200 200	0.78 3.21

TABLE 8.3 Trends in Static RAMs

YEAR	SIZE	COST $	SPEED (ns)	DISCOUNT TO 1978 @10%
78	1K*1	1.75	450	1.75
79	1K*1 1K*4 4K*1	1.6 6.95 14.95	300 300 300	1.45 13.6
80	1K*1 4K*1	1.6 9.5	300 300	1.2 7.38
81	4K*1	3.99	300	2.96
82	4K*1 2K*8	4.49 4.15	300 200	2.97 2.74
83	4K*1 4K*1	4.95 4.49	55 200	3.06 2.78
84	4K*1 2K*8	4.95 4.95	70 150	2.68 3.21

microcomputer problems directly related to the lack of memory will have practically disappeared by 1988. The cost of microprocessor chips and memory chips have decreased rapidly due to competition amongst manufacturers. When a new chip is introduced to the market and has no competition the price can be set by the manufacturer and is set high in order to recoup some of the research costs quickly. Once other manufacturers begin to produce equivalent chips the price starts to fall. Since a memory chip of 256K costs little more than that of 64K to produce it can be seen that the 256K chip should cost almost 3 times less than the equivalent memory made up of 64K chips. Likewise CPU chips also decrease in price, Figure 8.1 shows the decrease in relative cost of CPU chips with time.

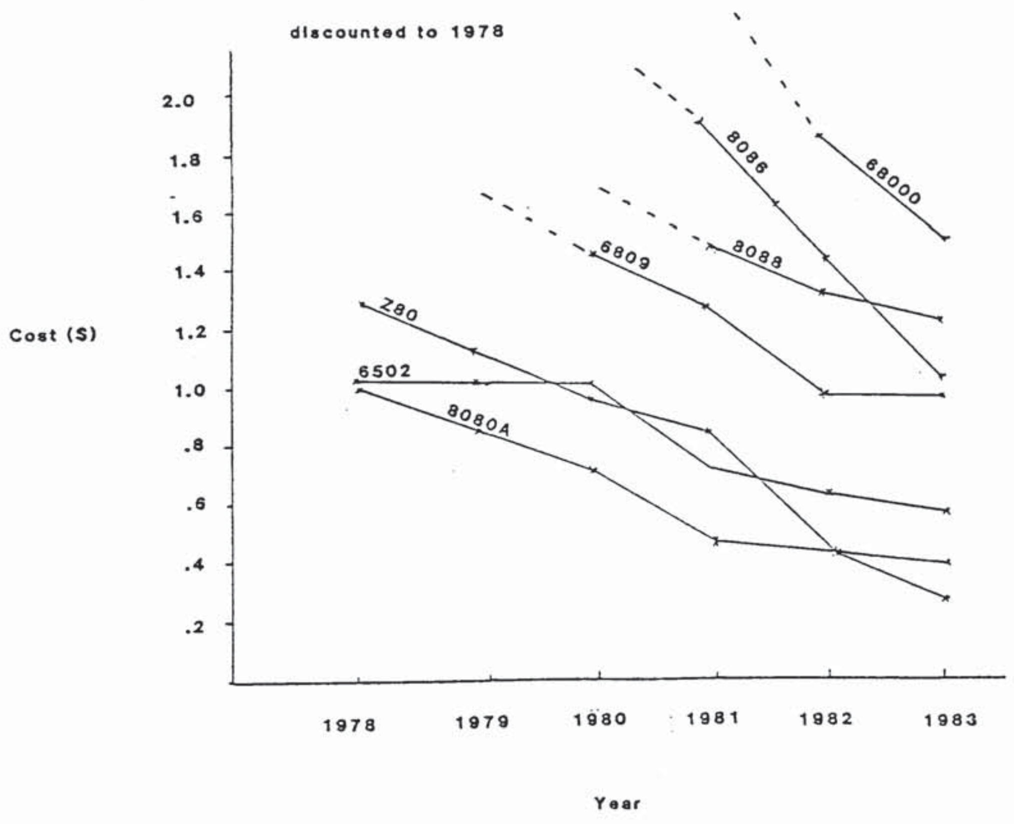


Figure 8.1 CPU Cost Over Time.

The average memory of a microcomputer today is 256K to 1/2 megabyte, this is expected to continue to increase, the IBM PC AT has announced a 4 megabyte RAM capacity (1985).

Backing storage is just as important as main memory since main memory is usually volatile and therefore programs and data have to be stored on some other media. Backing storage devices are usually electro-mechanical and although the cost of microelectronic components has decreased considerably over the past five years, electro-mechanical devices, such as the floppy disc drive, have not shown the same marked trend. However, such devices have improved considerably in terms of speed and reliability, often at no more cost than five years ago. Table 8.4 shows the storage capacity-cost relationship for some storage devices, (Chidley and Elgy, 1984).

TABLE 8.5 Capacity-Cost relationship for storage devices

	DRIVE COST ($)	STORAGE COST ($)	CAPACITY megabytes
Industry standard magnetic tape	3000-10000	20	-
Microcomputer streaming tape for hard disc	1700	5	20
Winchester disc	1000	5	20
Video tape drive	500	5	100
Floppy disc	120-300	1.5	0.5
Video disc	6000	10	1000
Laser disc	2500	0.6	4Gigabyte

The cost of 5.25" and 8" floppy disc drives have remained fairly constant, the emphasis has been upon improving disc and disc drive reliability and disc capacity. The cost of floppy discs has decreased in real terms over the past five years, however they seem to have reached their lowest possible price, (price is now based on production costs plus minimum profit). The 5.25" floppy disc has become the most widely used storage device in microcomputer systems over the past five years, with the 8" disc being used less and less. 5.25" discs were originally single density and single sided consisting of 35 tracks and 10 sectors. Continuing developments have now produced double sided, double or quad density discs of 80 tracks, and variable sectoring. Discs previously offered a maximum capacity of 150K, they can now offer up to 1.3Mbytes. The 3.5" disc drive was made commercially available on a system in 1983, and are expected to have 50% of the market by 1988. The reduction in size has not meant reduction in capacity but does provide improved access times and improved reliability. New packaging techniques have evolved and these have produced a far more robust envelope for the floppy disc, thereby improving disc and data reliabilty. The 8" floppy disc will have died out almost completely by 1990.

Winchester discs on the microcomputer have developed quite rapidly, and no longer exhibit their early reliabilty problems. In five years time, far more systems will have an integral hard disc, thereby increasing the total mass storage of a system. Laser discs will become more widely used, even though they are write-only discs they offer a massive capacity a reasonable costs and and faster access speeds.

Halcrow should carefully monitor the production of the floppy disc drive and the emergence of new standards over the next 2 or 3 years as the industry is in a state of change. The Sony 3.5" disc seems to have become the 'de facto' standard but there may be further innovations. It would seem futile for Halcrow to invest in systems using 8" drives.

Other peripheral technologies have not moved as fast as that for disc drive technology. Printers, for example, have changed very little over the past five years but it is expected that problems with noise, speed and size will be further addressed over the next three years. The trends in printer development have been to provide increased speed, larger memory buffers, more intelligence via the use of microprocessors, and to decrease noise production from impact printers. Printer developments expected in the future include dot matrix printers approaching letter quality output; impact printers becoming faster; the use of laser printers and ink jet printers with the larger microcomputer systems and futher development in non-impact heat printers. Dot matrix printers are closely approaching maximum speed without new technological innovations.

Since Halcrow are concerned primarily with the use of the microcomputer overseas it is suggested that they concentrate their introduction of printers to the high quality dot-matrix printers, since they are fast and will be able to produce documents of report quality in the future. Printers such as the laser and ink-jet type are expensive and unsuitable for most overseas situations due to their high cost and high sensitivity to their surroundings.

Screens have undergone various changes recently, and it is anticipated that these changes will become quickly adopted by the microcomputer manufacturers. The flat screen technology developed by Sony and Sinclair will have a significant impact upon portable computers (Financial Times, 1984). The alternative to these new developments is the standard CRT which has problems with heat, size and weight. Plasma displays have been developed by IBM, which can cope with 69 lines of 180 characters, but their cost is very high. Bit mapped screen facilities will be in far more evidence. Recent developments in the use of touch sensitive screens have been commercially successful but reliability has yet to be proved. Future developments in screen technology are expected to include flat colour screens and smaller screens with higher resolution.

Small hand-held portables will become more important in the field for the collection of data. Work such as measurement of water levels soil moisture, or radioactivity using probes attached to the input port, will be carried out with ease. Some data checking can be carried out in the field and any discrepancies can be reviewed without a second trip to the site. Data can then be brought back to base and transferred to a machine, or transferred via a modem (if the telecommunication system is reliable).

Communications is becoming a significant factor in the choice of microcomputers. There are various levels of communication to be considered. The most fundamental communications problem is the ability to pass data between one package and another, this is a major software problem and is further discussed in section 8.2. The next level of communication to address is that of communications between microcomputers. The provision of hardware and software allowing microcomputers to communicate with others of the same make, and to a lesser extent with entirely different types, (via a neutral format), is increasing. The major trends in communications will be a higher data transfer speed, the present standard of 300 and 1200 baud will increasingly be improved by orders of magnitude. British Telecom are already able to communicate at millions of bits per second on their lines, microcomputer ports will have to improve accordingly in order to efficiently utilise such improvements.

Networking is also an important trend for microcomputers, especially service networks which will allow individual nodes to have pre-ordained functions, such as a gateway node to other networks, letter quality printer, mass storage device etc. All of which lead to effective cost cuts by sharing expensive peripherals and data.

8.2 Software Trends

Whilst the cost of microelectronic components continue to fall rapidly, the cost of peripherals and software does not. The man-hours required to develop new software is increasing and becoming more costly as sophistication increases. Creative Strategies International, in a recent market research study, stated that the primary factor in deciding the success and the future of microcomputer companies in the 1980's will be the software available to be used on machines (Creative Strategies International, 1981).

8.2.1 Languages

Most languages available on mini and mainframe computers are now found in some form on the microcomputer. The expected trend is for these microcomputer languages to adopt some standard, since there are many versions of the same language available at present and this leads to many problems, particularly in communication capabilities. Although Basic is often thought of as the micrcomputer language there are various others which are just as heavily used, FORTRAN and COBOL being the most common. Both FORTRAN and COBOL are accused of being antiquated, however they continue to be quite resilient to changes and continue to be haevily used throughout industry. Although there have been many predictions for their demise (McCracken in 1970 forecast that no-one would be using COBOL by 1980), these languages continue to be used and demand means that new systems have to ensure these languages are available if they are to become successful.

With an increasing movement towards a standard operating system such as UNIX (see section 8.2.2) the use of high level languages, inparticular 'C' will increase. It is also expected that the development of a standard graphics package like the GKS standard on minicomputers will be developed. Microsoft langauges are widely accepted as an unofficial standard at present, whether they are adopted as the 'de facto' standard remains to be seen. It is envisaged that specialist high-level languages, such as SLAM, (a continuous simulation language) and interLISP, will be adopted more widely in the future for artificial intelligence and expert systems applications.

8.2.2 Operating systems

Two trends in operating systems appear to be emerging: firstly the need for the user to see the operating system is being eliminated enabling anyone to use the computer; secondly there appears to be an increasing trend for UNIX to be adopted by the 16 and 32 bit microcomputer systems. The speculation that IBM is going to adopt UNIX on their PC AT has furthered the cause of this operating system, and many expect UNIX and UNIX derivatives to become the standard for the future microcomputer. The developing trend of multi-user systems is very important since it allows the sharing of multi-user systems is very important since it allows the sharing of common databases, programs and equipment and makes for software portability. Such systems also require a higher degree of security. A multi-user operating system is a pre-requisite for local area networking.

The increased sophistication of microcomputer systems is allowing the microcomputer to be favourably compared with some of the smaller scale mini-computers. This increasing sophistication is leading to the necessary inclusion of on-line help documentation as found in minicomputer operating systems (e.g. VAX/VMS, Data General AOS/VS) This requirement for documentation may be one of the applications of packages to be stored in ROM, since it is predicted that more software will be stored in ROM chips, particulary since ROM chips of 256K are now available. This trend will also discourage software piracy.

8.2.3 Software costs and productivity

Although hardware costs have been decreasing at a very rapid rate, software costs have not. Software forecasting is more difficult to quantify than hardware. According to Wise et al (1980) a typical small system in 1975 cost $100,000, but the software cost $200,000. Therefore software was costing 67% of the system in 1975. By 1990 software is expected to cost 85% of the total system. Boehm (1975) in looking at hardware/software costs predicted that software costs would have risen to 90% of the total system costs by the late 1970's.

Software sophistication has progressed at a far slower rate than that of hardware. While the latter is in the realms of Very Large Scale Integration, languages such as FORTRAN, which was developed in the mid 1950s, are still being used extensively (although they are undergoing a steady metamorphosis). Unless software development tools are improved in the near future, the effectiveness of improvements in hardware will be greatly reduced. Software productivity has been little changed over the past 20 years. Computer Talk (1983) claim that the production of one line of program code costs the same today as it did 25 years ago, although applications and code then were less sophisticated than now. The advent of the 'Supermicro' with its massive memory and very fast execution speeds causes two arguments to arise:

1) In order to make the most of the newer, more powerful systems programmers will have to improve both software productivity and software sophistication.

2) Because the newer systems will be far larger and faster, programmers will not need to be as efficient as they are now - programs will easily fit into memory and run faster than previously.

Since hardware costs are continually decreasing the cost and production of software is a key element in forecasting the type and cost of total systems of the future. In order to measure the feasibility of using microcomputers overseas, software will have to be examined and prices forecast. The cost of hardware will be easily covered by most overseas projects or merely be lost within the budgets of the project at hand. Software however, has many other implications which must be considered. With an increasing importance being placed on software Halcrow will have to become more aware of the consequences of developing software on overseas projects. Cost of software development will have to be calculated.

The awareness of software legalities will increase with software houses taking legal measures to protect their goods. Software leasing (including operating systems) is also expected to increase and the sale of software under license and the leasing of software will increase.

Software costs can be divided into three major areas:-

a) Operating systems- which are increasing in cost as they increase in sophistication but are most often given free with the system. If the user wishes to use an operating system other than that given by the manufacturer costs will be significantly increased.

b) Software Packages- these vary considerably in price along with function, as new versions of general packages (e.g. databases, spreadsheets etc) are made available the cost increases slightly due to improved sophistication. Since there is an expected continuing boom in the sale of microcomputer systems in the next five years, there is a possibility that certain general software packages may begin to decrease in price. However, new and improved specialist packages can be expected to increase considerably in price.

c) In-House Programs- In chapter 6 a method for software cost estimation was put forward.

Although software costs are very high and authors are expecting software to cost between 75% and 90% of the total system cost by 1990, there are many factors to take into consideration. Civil engineering consultants will probably not experience such a large percentage increase in software costs as other industries since they do not actually employ highly paid computer programmers but prefer to train civil engineers to use microcomputers.

8.2.4 Fifth generation systems

There is much talk about fifth generation systems and the consequences they are to have upon the future. This interest has mainly stemmed from the announcement by the Japanese in 1981 that they had already commenced a large research and development project on fifth generation systems, in which knowledge based systems were a major focal point. In order to exploit fully the new software ideas, radical changes in hardware development were to be made, (D'agapeyeff, 1983).

There are many aspects of fifth generation computing which have caught the imagination of the British Computing fraternity. Such terms as "expert systems" and "information technology" have been used increasingly. In March 1982 a committee was set up by the Minister for Information Technology to review the flow of information technology in the UK and to examine the ability to gain collaboration in a research programme. The Japanese were seen as a major threat to the UK, which was hightened by the ability for the Japanese to secure a national collaboration and cohesiveness in a computer research programme which was seen to be extremely difficult to achieve in the UK due to conflicts and distrust amongst the industry and academia.

The Alvey Report, (1982) recommended that the government should launch a national programme on information technology (IT). The major areas to be explored were to be software engineering, very-large-scale integration (VLSI), man-machine interfaces, and knowledge based systems. The government was recommended to provide funding for academic research and up to 60% of funding for industrial research. The programme was estimated to take 5-8 years with annual reviews and reset targets and it was felt the programme would be essential to the competitiveness of the UK IT industry.

One of the major aspects to emerge from the Alvey Report has been the development of database systems on the microcomputer and the increasing development of expert systems, using such languages as PROLOG and LISP. PROLOG is the language which the Japanese have adopted as their fifth generation computer standard. In civil engineering consultancy the ability to build knowledge based systems particularly expert systems is extremely promising. Halcrow should monitor the development of such technology (particularly software) closely and will have to adopt these new techniques if they are to remain in competition with consultants not only of this country but of other European and Far East consultants. Whilst such systems threaten the employment of some engineers, lack of employing the latest technology will mean lack of work.

8.3. Overall Implications Of Future Trends

Hardware sophistication is expected to improve. VLSI methods will be used to develop custom built chips for voice recognition and synthesis, graphics capabilities, communications etc. 16 bit and 32 bit microcomputers will be most important with the 8 bit microcomputer slowly disappearing. Software will have to improve in order to make use of improved hardware.

The main trend of total systems over the next five years will be to get more hardware and more memory for less money. In five years time average systems are expected to be of at least 2Mbyte memory and 20Mbyte mass storage as opposed to an average system of today of 256K and 500K-5Mbyte mass storage. Mass storage will become almost limitless in size and access speeds to discs will improve. The laser disc will become widely used. Communications and artificial intelligence devices are expected to rise rapidly in importance. Portable microcomputers with extensive memory, portable Winchester disc, flat screen and good communications capabilities about the size of a briefcase will be devloped.

A growth rate of 35%-40% per annum in the purchase of microcomputer systems is expected over the next five years (Computer Weekly, 1983).

CHAPTER NINE DEVELOPMENTS DURING RESEARCH

During the past three years Halcrow have continued to use microcomputers both on overseas projects and in head office. Various developments have taken place and are be described in the following chapter.

9.1 The Use of Microcomputers by Halcrow

The Commodore microcomputers bought in 1981 were highly successful in providing an experimental basis for writing applications for overseas projects and exploring the potential of such equipment. Perhaps more importantly, they served to familiarise members of staff with microcomputers and stirred curiosity from some of the non-believers. A 'softbox' (comunications device) was also purchased for the system which would allow both CP/M and FORTRAN-80 to be implemented, and facilitate communication with the company's Prime minicomputer. Unfortunately very little use was made of the softbox, probably because of the poor manuals and lack applications, and any potential benefits were not realised

The management of the Commodore systems was highly organised with a set of program libraries and cataloging of software being maintained. The program library consisted of five types of disc:-

1) program discs
2) data discs
3) pre-recorded discs
4) duplicate discs
5) back-up discs

There were three types of program disc:-

a) programs available for general use - PROGRAM LIBRARY

b) programs under development for which no documentation exists - DEVELOPMENT LIBRARY

c) programs developed for system manipulation - SYSTEM LIBRARY

This organisation was facilitated by the microcomputer being kept within a small section of the company and by the eagerness of the managers who chose the system to prove its worth.

Once managers began to realise the potential of microcomputers they were included in an increasing number of project tenders, and eventually used on various projects. With the large choice of microcomputers on the market and the increasing developments of the technology sections of Halcrow moved away from the Commodore systems. This diversification is seen to have both advantages and disadvantages. By adopting a standard system there would be the advantage of being able to pass software from one project to another. There would also be the ability to interchange hardware between head office and project sites. A back-up facility is automatically created by standardising hardware and software, and staff would become increasingly familiar with the equipment being used. The main disadvantage is that since the microcomputer industry is moving at such a rapid rate, any standardisation would be quickly out of date leaving the company behind yet again.

The microcomputers that have been bought for overseas projects have varied according to the type of project and the project manager making the choice. Portability has been seen to be one of the most important aspects on overseas projects and for this reason the Osborne 1 computer has been either bought or leased for several projects.

On one project in which no maintenance could be expected in the area in which the microcomputer was to be taken Halcrow arranged for some members of the project team to undergo a crash course on hardware engineering and the repairing of an Osborne system. Whether the team could have coped with a breakdown is difficult to assess since no faults occurred on the project. On certain short term projects an Osborne microcomputer has been leased by Halcrow to be taken overseas.

Along with an increase in the use of microcomputers on overseas sites, there has been a lack of software management. The organisation of software for the Commodore microcomputers has not been adopted for other systems. A lack of communication between sections of the company has also meant that staff are not aware of the software available for the microcomputer within the company and therefore even if it is already available it has to be rewritten. Where software is known to exist it is usually accompanied by poor or no documentation, making it difficult for others to use and to trust.

A microcomputer sub-committee was formed in 1982 to investigate the introduction of microcomputers within the Halcrow Water Company, particularly with respect to training, usage and choice of microcomputers. The formation of such a body has resulted in a training course being set up, (as mentioned in Chapter five), upon which all levels of staff have been sent, including directors. The training course was arranged with the Civil Engineering Department of a university and included introductions to CP/M, Supercalc, DBase II and Wordstar. 60 members of staff were sent on the course, (8 on each day). Each participant was also allocated 20 hours of worktime to be spent using microcomputers and reading relevant literature in order to become fully acquainted with such equipment. Self-teaching discs were provided by the course tutors to help with the learning of BASIC.

A questionnaire was designed and sent to those who had attended the course in order to find out whether the training course had been worthwhile. An internal report on the survey was provided for Halcrow and is given in Appendix G. The results of the survey were encouraging, most said that the course had been useful in making them aware of the use of microcomputers and gave them confidence to use microcomputers in the future.

There are still many problems that need to be tackled by the sub-committee if the company is going to realise the benefits of using such equipment.

During the three years of this research the awareness of the impact of microcomputers by Halcrow staff has increased. At the begining of the project there was little awareness of the capability of the microcomputer. The overall attitude of engineering staff was one of lack of interest and understanding. This attitude has dramatically changed over the past three years. Most engineering staff at all levels have accepted the new technology and many are using it at any opportune moment. However the level of planning and management is not as high as it should be. The following section will discuss proposals made to enhance the use of microcomputers.

9.2 Proposals

There are various measures which Halcrow could take in order to improve their use and understanding of microcomputers:-

1. Development of a software library:- the library system set up for the Commodore microcomputers worked well and should be adopted on a larger scale to include all software developed for and on overseas projects. This could be done by setting up a central software library in head office, ensuring that all software developed was brought back

to base and made available for other users.

2. Liason with overseas projects:- project managers need to be able to liase with a 'troubleshooter' at head office. At present any computer problems are passed back to head office in the hope that someone knows the answer or understands enough about the system to be able to liase with the sales agents.

3. Liason with sales agents:- Instead of each each individual project team arranging for equipment from sales agents, it would be preferable to have one person in head office who could establish a relationship with several computer dealers in the area and therefore be able to negotiate reasonable discount facilities for the company.

4. Assistance for Project managers:- at present the project mangers choose microcomputers on personal preference, hearsay and sales talk. Although a methodology for the choice of a system has been provided earlier in this thesis (Chapter 6), it would be easier and less time consuming if the manager could liase with a specialist in microcomputer technology. This specialist should be able to provide information on the latest systems and be able to advise on the most appropriate systems for a particular project.

5. Software availability:- in order to eliminate the rewriting of various pieces of software a cataloging system should be adopted and a memmoradum circulated every two months (at least), to overseas project sites and head office sections . The memos should give advice on new software developments and the availability of the programs on various machines.

6. Research and'development:- so far all research and development on microcomputers in Halcrow has been fragmented. It would be useful to have someone review the work being carried out by varoius projects and

look at applications which have not yet been developed.

7. Software Portability:- there needs to be the facility to move software from system to another, a requirement which involves an understanding of systems software and communications.

8. System routines:- many engineers are using microcomputers for simple applications using common software packages. When they need to program at a more complex level they find the systems jargon difficult to understand. They need to be able to get advice on writing systems routines or have them written by someone who is more familiar with systems software.

9. Software Pool:- by buying software centrally it could be pooled and copied (within copyright laws), thereby saving the total cost of software packages with each new system.

10. Competitors file:- it is always useful to know what your competitors are doing. It would be useful to keep a file, principally from press cuttings, of the use of microcomputers by other consultants. This will reveal the state of the civil engineering industry and how Halcrow is faring compared with other consultants.

11. Training:- the training courses should be continued with more specific courses for certain packages such as DBASE II, and periodic refresher courses. The provision of a training room with computers and other training materials would be useful.

Figure 9.1 shows that all the above proposals could be co-ordinated by a microcomputer manager. The position would be quite different from the role of the computer manager already employed. The microcomputer manager should be able to liase with directors, management, and staff and be able to understand and cope with a civil engineer's specific needs. He should be able to co-ordinate the use of microcomputers within Halcrow, and be able to give the micrcomputer sub-committee advice on issues of planning and management.

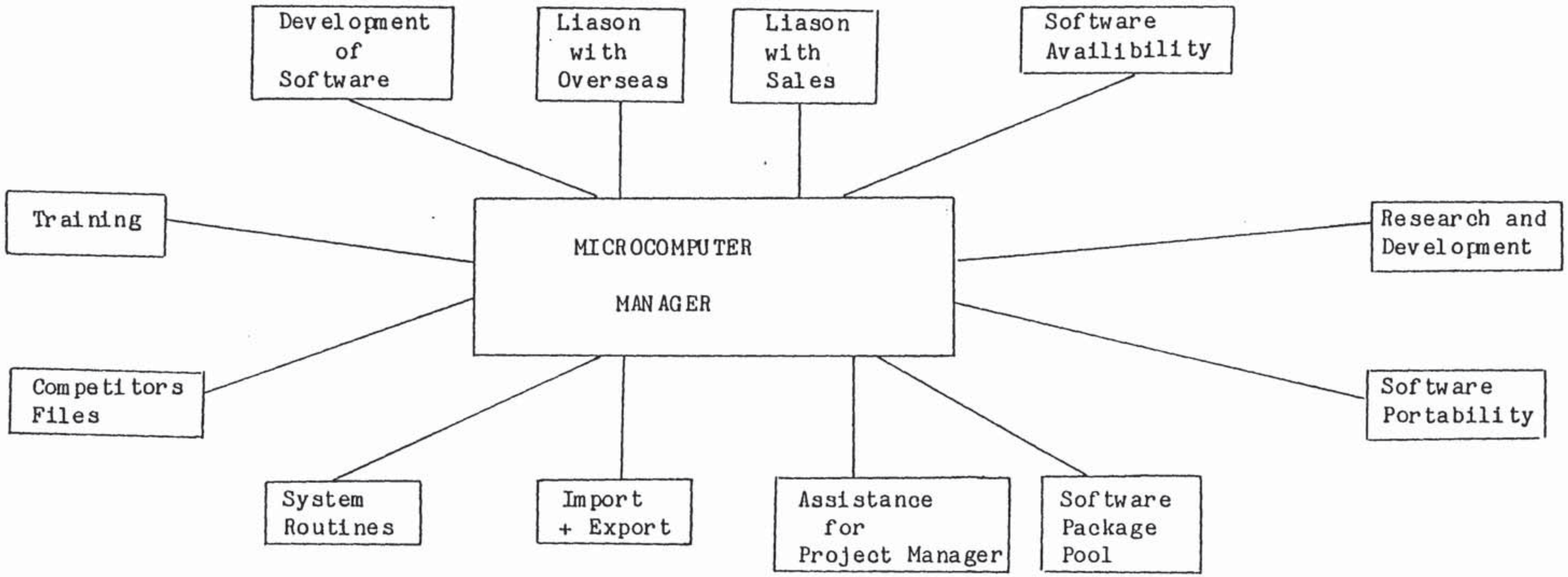


Figure 9.1 Role of a Microcomputer Manager

CHAPTER TEN CONCLUSIONS

The microcomputer market is progressing at such a rapid rate, that systems now in use will probably be looked upon as obselete in three to four years time. The principle objective of this thesis was to evaluate the feasibility of the microcomputer as a tool to provide a competitive edge particularly on overseas projects.

Civil engineering consultancy in the UK has been slow compared with USA consultants in taking up the new technology, this was particularly apparent from the literature review. Several authors in chapter 3 related this lack of use to the high cost of software and the lack of good, readily available software. The research carried out found that there is still a lack of good engineering software but the amount of general software packages is high. Therefore, the microcomputer cannot be regarded as a cheap option if it is only to be used for engineering/technical applications.

The survey of UK consultants showed that many companies were begining to regard the microcomputer as a serious tool and were using it for various applications.

The competition for overseas consultancy work is no longer largely made up of UK consultants. European and Far Eastern companies now tender for far more overseas projects than previously and pose a serious threat to the livelihood of the UK consultants. The use of new technology such as the microcomputer on overseas projects was seen as one way of gaining a competitive edge. Crozier-Brown (1978), had stated that civil engineering companies would have to use new technology in order to survive. It has become increasingly apparent during this research that clients and funding agents expect the use of new technology upon projects they instigate. One of the main benefits of using microcomputers appeared to be that of being seen to use such technology. As microcomputers have become more widely used the novelty has worn off and consultants are going to have to show that the equipment they use can produce results cheaply and more efficiently than old techniques.

There are many factors involved in the choice of microcomputers for use on overseas projects, although cost is usually the over-riding factor. With a particular overseas project in mind the numerous factors involved can be itemised and the method for choosing a microcomputer somewhat rationalised. A methodology for determining which microcomputer to choose was developed in Chapter 5. It is important to remember that the basic capabilities of the microcomputer are the same as any other computer, namely, speed, accuracy, memory capacity and data reproduction. For the microcomputer to be feasible it is important to use it for applications for which it is most suitable. The microcomputer's ultimate abilities are to carry out repetitive tasks and provide a data filing system, therefore presenting itself as a tool for both engineering problems and effective management.

In Chapters 6 and 7 the feasibility of using microcomputers on site was examined by reviewing the actual use of microcomputers on various projects and, by programming two engineering applications. In Chapter 6 the review of microcomputers on various projects took two approaches: firstly, two projects were examined in the field and secondly a cost benefit- analysis on an overseas project using a microcomputer was carried out. In chapter 3 Taffs (1981) had claimed that from his experience microcomputers were not cost-beneficial and they were not the answer to improving competitiveness. The results from the cost-benefit analysis carried out in Chapter 6 showed that benefits far outweighed cost. The microcomputer allowed improved engineering results to be produced, which could not have been produced economically using traditional methods. The two technical applications tackled in Chapter 7 also showed that although software costs are high the results and benefits make the microcomputer highly feasible, particularly for overseas projects where it is often difficult to find adequate computing power available. Microcomputers are an important aspect of competitiveness on overseas projects. Clients are impressed by their use and in many cases see them as a step towards their escape from third world status. Not only have microcomputers been producing improved results , they also present to the client a technology which until recently he has had difficulty in aquiring. In several cases where Halcrow have used microcomputers the client has asked them to continue further with the project or they have been assigned to relating projects.

Due the nature of civil engineering consultancy work two important aspects of using a microcomputer are software reliability and the consequences of liability for poor or failed software. Bowles (1981) raised the point of software reliability and stated that software familiarity and good documentation were essential, (chapter 3). It has been noted in the thesis that microcomputers will only be cost-beneficial if they are properly managed and their use is effectively planned. The results of the haphazard and poorly planned use of microcomputers by civil engineers will be the production of poor software with liitle or no documentation. This type of software can only be used with any confidence by the writer. Consequently, the company will begin to incur high software costs because each project will result in the reproduction of basic programs.

During this research microcomputer hardware has continued to fall in cost and increase in power, with several microcomputers now approaching the power of the minicomputer. However, software has not shown such marked decreases in price and the cost of developing software continues to rise. Trends in microcomputer technology suggest that hardware costs will continue to fall, whilst software development costs will increase, but the cost of general software packages will possibly fall slightly with increasing demand and sales.

Halcrow Water Company had realised that microcomputers had possible potential in providing a competitive edge over other companies in their use on overseas projects. They could not have forecast the speed with which microcomputer technology has moved over the past three years, but have continued to pursue the benefits of the microcomputer and have used them on various overseas projects. However, to achieve and maintain a competitive edge it is no longer sufficient merely to propose the use of a microcomputer on an overseas projects, since other consultancies have also become aware of the state of the technology as have the overseas clients. To maintain their competitive edge it is no longer adequate to be seen to be using the latest technology. They must be able to demonstrate highly professional skills in the use of microcomputers. These skills are dependent upon good training facilities, planning and management. Halcrow should agree on a company policy for the use of microcomputers which must be endorsed at management and director levels in order to organise the efficient use of microcomputers and provide back-up and problem solving facilities. Halcrow should provide proficient facilities at head office, including the appointment of a microcomputer manager. The microcomputer manager should advise on the planning and management of microcomputers both in head office and on overseas projects.

Microcomputers will be an important tool of the future for the civil engineering industry and by efficient planning and management Halcrow and their clients will benefit from their use.

APPENDIX A - INPUT/OUTPUT TECHNIQUES

In an interrupt driven system, the I/O device has the initiative for requesting service. Each device when requesting service from the microprocessor unit generates an interrupt signal along the interrupt line (see figure A.1). Accepting or refusing an interrupt is implemented with an internal mask bit, normally stored in a status, (or flag) register. When an interrupt is generated, the microprocessor must determine which device has generated that signal, then branch to an interrupt handling routine. Often more than one device has to be connected to an interrupt line, but the number will depend upon the processor's capabilities. Whenever multiple devices are connected to the same interrupt line, priorities must be assigned to those devices in order that the microprocessor should know which to service first. For example, a floppy disc unit might have priority level 1, whereas a power failure detect will have priority level 0. Whenever an interrupt is generated all devices with a lower priority will automatically be disenabled, or masked.

Interrupts are often found to be too slow for some devices, e.g. CRT displays which must be refreshed regularly, and in some cases, another technique has to be used. One of the most commonly employed is direct memory access (DMA), a hardware technique which speeds up the process significantly. In a DMA I/O operation the CPU is bypassed completely. Data transfers do not take place through the accumulator or general purpose registers. Instead, transfers take place directly between memory and the peripheral devices, this is shown in figure A.2.

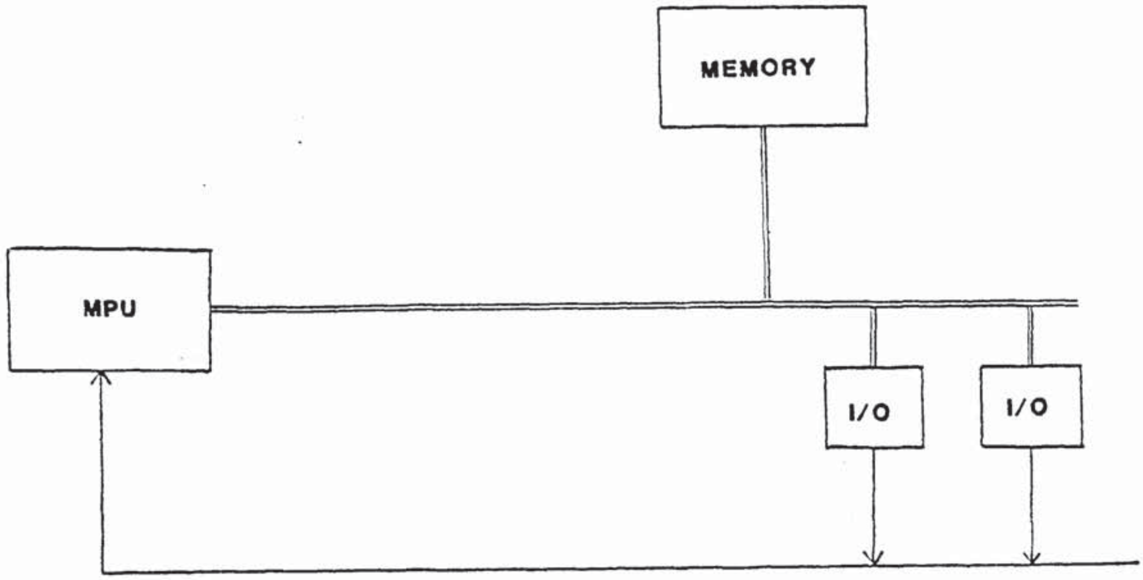


FIGURE A.1 Interrupt Mechanism

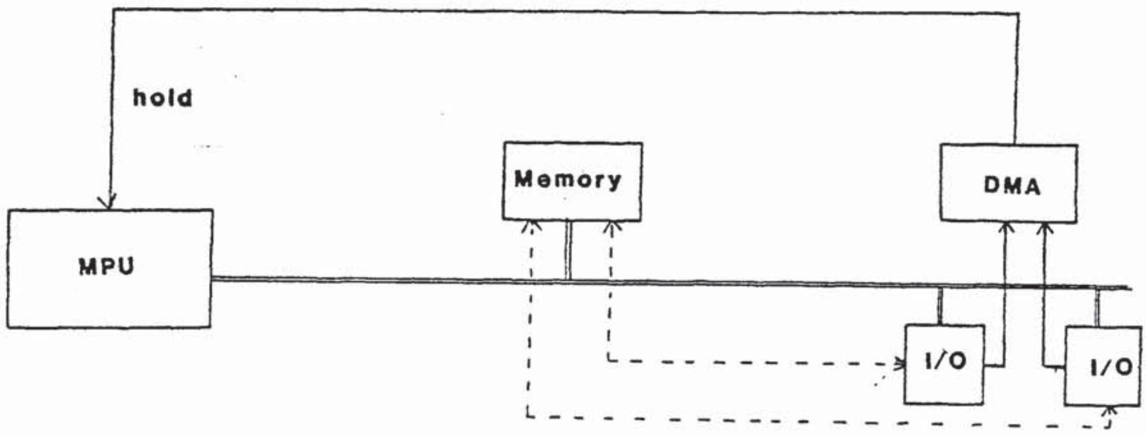


FIGURE A.2 DMA Mechanism

APPENDIX B OPERATING SYTEMS

CONTROLPROGRAM/MONITOR (CP/M)

CP/M is a highly-Successful 8-bit microcomputer operating system, originally developed for use with the Intel 8080 microprocessor, (Powys-Lybbe,1981). CP/M is divided into three basic parts: the BDOS, BIOS and CCP. BIOS is the basic input/output, (I/O), system, which is a hardware dependent module defining the exact low level interface for peripheral devices. BIOS can be reconfigured to suit the hardware being used. BDOS is the basic disc operating system. BIOS and BDOS are usually combined and regarded as the FDOS, with a common entry point. FDOS is the resident part of the operating system which it must remain in memory during the execution of the user's program.

The CCP, (command control processor), is a distinct program which reads the user's command entered through the console. It contains six built-in commands, as follows :-

DIR	-	list filenames in directory
ERA	-	erase specified filenames
REN	-	rename specified file
SAVE	-	save transient program area (TPA), memory contents in a file.
TYPE	-	list the contents of a file
USER	-	change the currently logged user

These commands execute programs located within the CCP, whereas there are many other transient commands which need to be loaded from disc and executed within the transient program area (TPA). TPA can overlap CCP, since CCP is never required during program execution. CCP is automatically reloaded at the end of program execution. The following transient commands are available on CP/M :-

ASM	-	assemble a specified file
DDT	-	the CP/M debugger

DUMP - dump the contents of the file in HEX

ED - the CP/M character editor

LOAD - create a user-transient command from a HEX (Hexadecimal), machine code format

MOVCPM - regenerate CP/M for different memory sizes

PIP - peripheral interchange program

STAT - provides statistical information on files

SUBMIT - submit a file of commands for execution

SYSGEN - create a copy of CP/M on floppy disc

XSUB - extends the submit command to include batch responses

A full explanation of the above commands can be found the the CP/M manuals.

CP/M files are maintained by name, in a directory on each disc. Two types of filename are recognised: the internal filename which resides in the disc directory; and the external filename used by CCP. A filename consists of two parts: the actual name of the file , which can be up to 8 characters long and the filetype which is optional and up to 3 characters long, separated by a full stop. A file may be of any size from 0 sectors to a full disc. The file size is mapped in blocks of 1024 bytes, although CP/M transfers files in 128 bytes to the TPA. These blocks may spread over any part of the disc, although to the user they appear as one contiguous sequence. The mapping of the file onto the disc and its following management is recorded in the file control block, (FCB), on the disc. The FCB is created by the program or CCP maintained by the BDOS, and saved in the disc directory. The FCB is 33 bytes for every 16Kbyte of each file.

The main reason for CP/M's success is attributed to its development, which, unlike most microcomputer operating systems, departed from a rigid hardware dependence. By developing the BIOS, where CP/M's hardware dependant portions are concentrated and, by allowing the user to reconfigure this area to the user's own particular requirements, CP/M offers the user a great deal of flexibilty . Another important factor contributing to CP/M's success is the massive amount of software developed for CP/M, including FORTRAN, ADA, COBOL and many application packages, e.g. Wordstar, DBase II, spreadsheet and financial planning packages.

CP/M is not the easiest of operating systems to use. It is not 'user friendly' and has a habit of displaying totally incomprehensible error messages, e.g. BDOS ERROR , which is totally meaningless to most users, or crashing completely when an error occurs. CP/M's commands are not readily identifiable, e.g. TYPE, meaning list a file. CP/M also appears extemely cumbersome and long-winded on occasions, particularly with commands like PIP,(Peripheral Interchange Program). CP/M's weakest point appears to be its editor, being difficult and awkward to use and not successful in its operation. Many CP/M users prefer to disregard the editor and use a word processing package such as Wordstar to edit and create their files. CP/M's manuals, produced by Digital Research, are very poorly explained.

CP/M's strength lies in the number of users it has acquired. There are over 90 microcomputers which will run CP/M. Software houses have seen this as an opportunity and continue to develop massive amounts of CP/M compatible software.

UNIX

UNIX was developed by Bell laboratories in 1969, as a single user version for the DEC PDP7 and the DEC PDP9 minicomputers, (Sadler and Eisenbach, 1981). Today it is well known as the DEC PDP11 operating system. However, because UNIX is written in the C language, there have been several attempts to utilise fully UNIX on the larger, 16 bit microcomputers.

The UNIX filing system is a hierarchical tree structure, whose root is a directory and the final branches are the programs and data files of the system and the users. Discs full of files, organised as subtrees, may be attached to the main tree at any point. Each file, (including directories), comprises a sequence of characters followed by an end-of-file marker. At any given time, a user will occupy some position in the tree, which can be changed easily in order to manipulate the files in the neighbourhood. Additionally, I/O devices are simply treated as files in the directory, therefore making it very straightforward to direct input or output, e.g. output to a line printer would be as follows :-

```
$ file/dev/slp                where :- dev = path
                                       slp = serial line printer
                                       $   = unix prompt
```

The UNIX command interpreter is a program called the Shell. Most commands are two letters, e.g. LS, which executes a program called LS, to list the filenames on the terminal. The Shell assumes the user's terminal is the default I/O device.

UNIX provides some security to users in the form of a password system. Each user logs into a named area on the tree and must supply a password to gain access. There are three access rights: read, write and execute. There are also three user labels: owner, group and world. The password is in an encrypted form.

UNIX assumes the user is intelligent and, there is little provision to keep a user from making mistakes, short of error diagnostics. UNIX is known to require comparatively large amounts of memory and disc space. The real strengths of UNIX are said to lie in its adaptability. It has the ability to accept patching, or rebuilding as the program environment evolves, and to migrate to foreign hardware. Since the bulk of UNIX is written in the language C, one simply requires a good C compiler, and apart from device handlers, a few hardware-specific routines and a few time critical routines. The whole system can be built like an ordinary program.

The UNIX editor is quite difficult to use, largely because there are no prompts given, making it difficult for the user to know his actual position in the file.

UNIX offers the following languages: APL, BCPL, LISP, AlGOL 68, POP, PASCAL and FORTRAN 77.

APPENDIX C <u>TEST PROGRAM</u>

The following program was run on several microcomputers in order to examine computer performance. In all cases the BASIC interpreter, not compiler, was used and the results were noted.

```
1 REM TEST PROGRAM
2 C=1
3 Y=23
4 GOTO 8
5 RETURN
8 PRINT "BEGIN LOOP"
10 FOR I=1 TO 10000
20 NEXT I
25 PRINT "END LOOP"
28 PRINT "BEGIN ADD"
30 FOR I=1 TO 10000
40 C=C+10
50 NEXT I
55 PRINT "END ADD"
58 PRINT "BEGIN COSINE"
60 FOR I=1 TO 10000
70 X=COS(Y)
80 NEXT I
85 PRINT "END COSINE"
88 PRINT "BEGIN TANGENT"
90 FOR I=1 TO 10000
100 X=TAN(Y)
110 NEXT I
115 PRINT "END TANGENT"
118 PRINT "BEGIN DIVIDE"
120 FOR I=1 TO 10000
130 C=C/2.3
140 NEXT I
145 PRINT "END DIVIDE"
148 PRINT "BEGIN JUMP"
150 FOR I=1 TO 10000
160 GOSUB 5
170 NEXT I
175 PRINT "END JUMP"
180 PRINT "END PROGRAM"
```

APPENDIX D MICROCOMPUTER TEST PROGRAM

The following problem was given to people taking part in the software productivity experiment:-

Write a program to read in a date and print out what day of the week the date corresponds to. The day can be calculated from the following equation.

$$\left(\left[2.6M - 0.2\right] + D + Y + \left[\frac{Y}{4}\right] + \left[\frac{C}{4}\right] - 2C\right) \bmod 7$$

D - is the day of the month

M - is the month number taking March as 1 up to December which is 10; January and February are months 11 and 12 of the previous year.

C - is the century

Y - is the year

The square brackets indicate that the result is to be truncated, i.e. everything after the decimal point is dropped.

Mod 7 means that the result in round brackets is divided by 7 and the remainder taken to find the day. If the expression in round brackets yields a negative number add 196 before dividing by 7.

The remainder indicates the day, according to

0 = Sunday, 1 = Monday, 2 = Tuesday, 3 = Wednesday, 4= Thursday, 5 = Friday, 6 = Saturday.

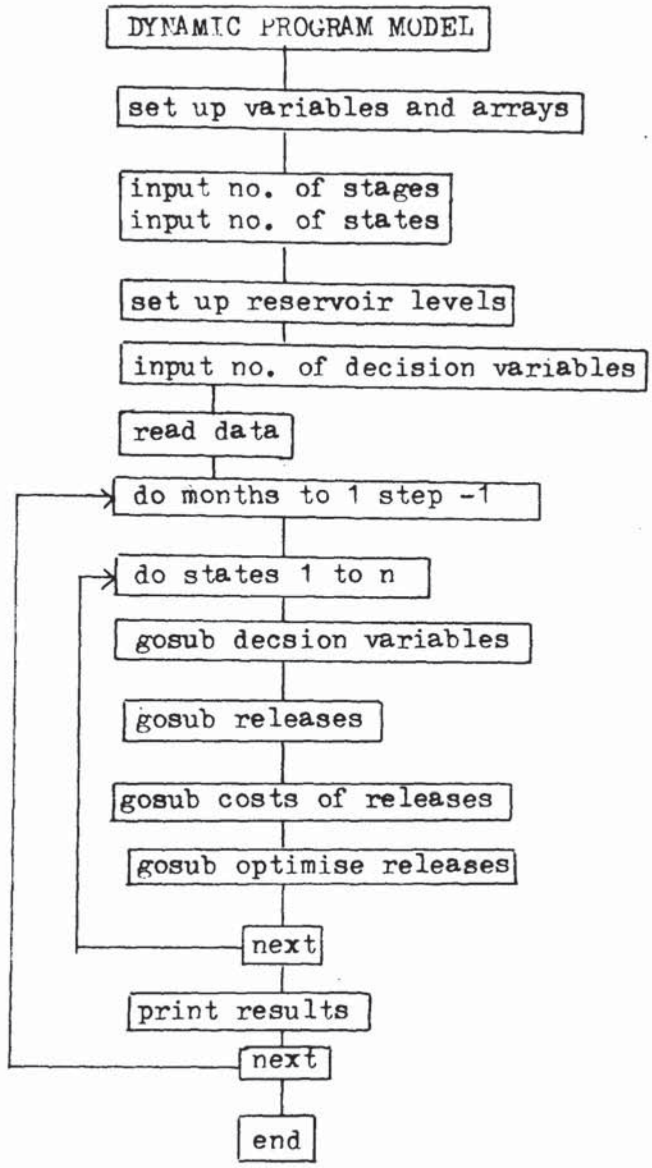
E.g August 14th 1975   M = 6 D = 14 C = 19 Y = 75

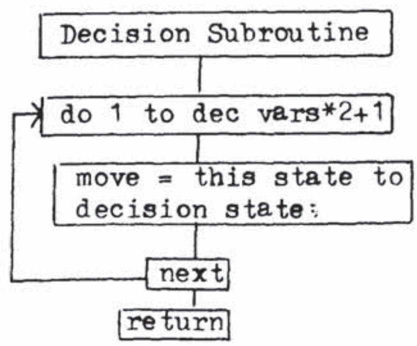
$$\left(\left[15.6 - 0.2\right] + 14 + 75 + \left[\frac{75}{4}\right] + \left[\frac{19}{4}\right] - 38\right) \bmod 7$$

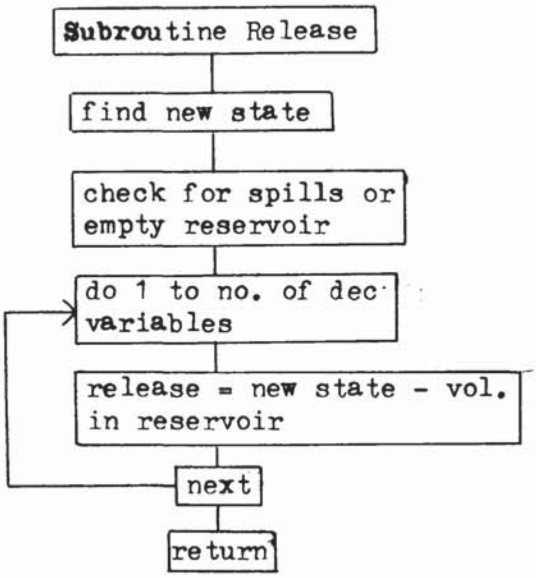
$$(15 + 14 + 75 + 18 + 4 - 38) \bmod 7 = \frac{88}{7}$$

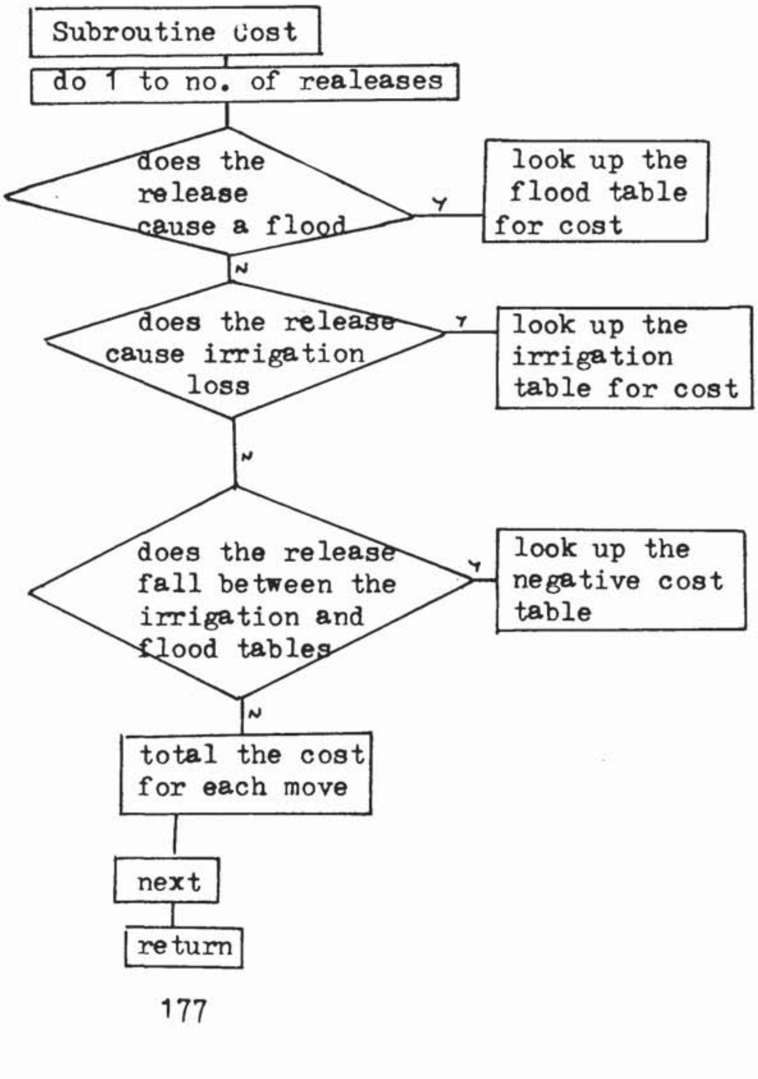
Remainder 4 so August 14th 1975 was a Thursday

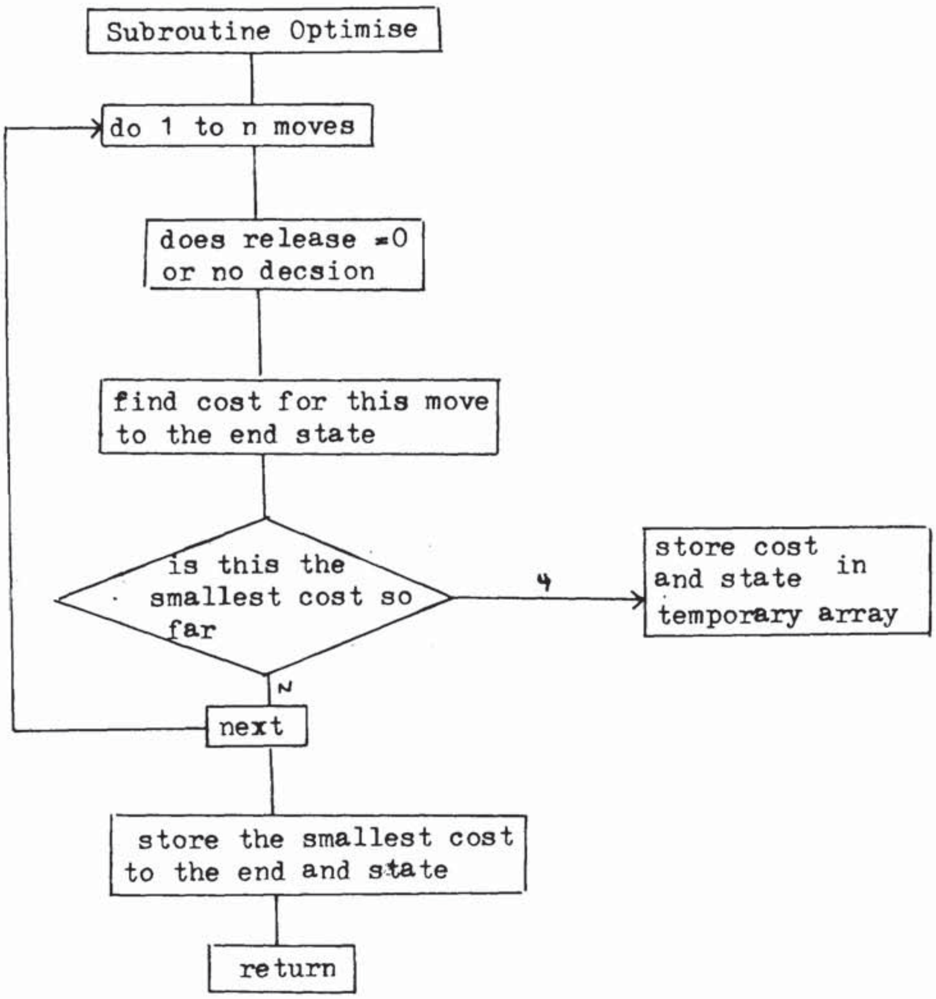
APPENDIX E <u>DYNAMIC PROGRAMMING FLOWCHART</u>



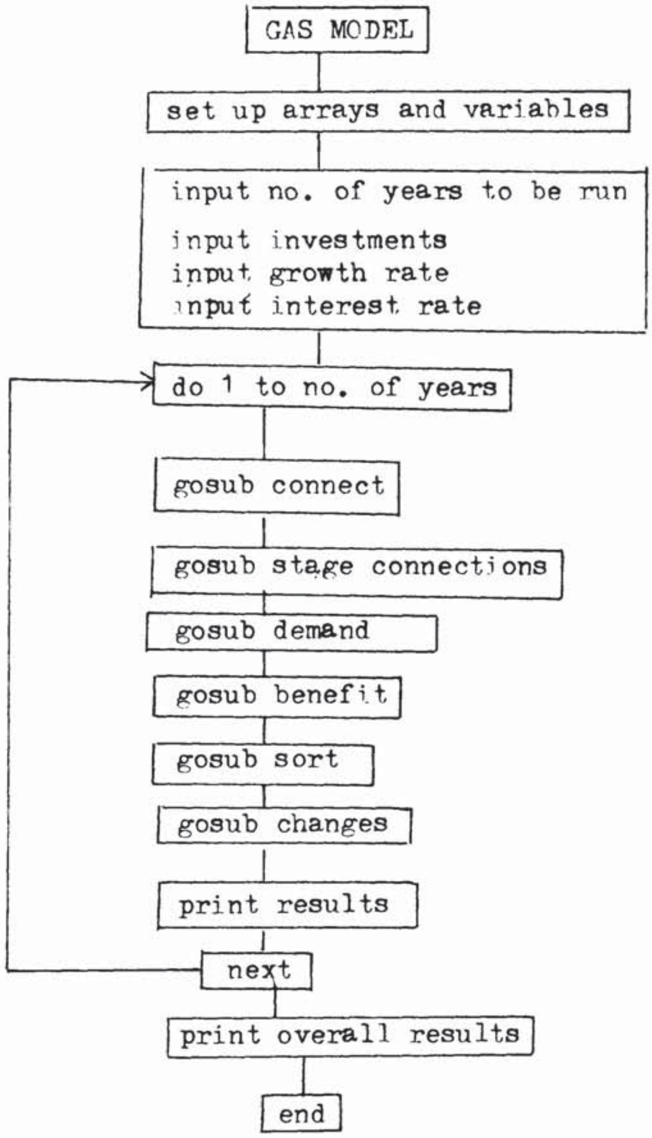


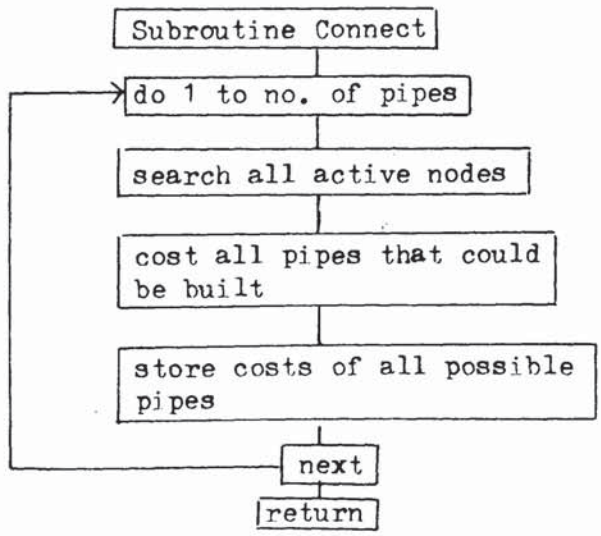

Subroutine Release
find new state
check for spills or empty reservoir
do 1 to no. of dec variables
release = new state - vol. in reservoir
next
return

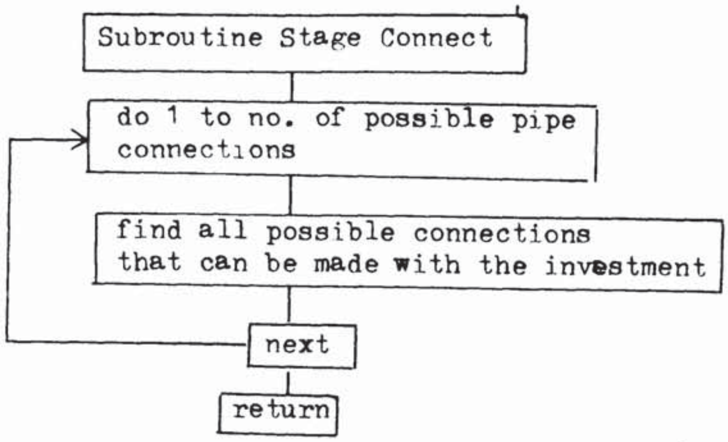

Subroutine Cost
do 1 to no. of realeases
does the release cause a flood
Y
look up the flood table for cost
N
does the release cause irrigation loss
Y
look up the irrigation table for cost
N
does the release fall between the irrigation and flood tables
Y
look up the negative cost table
N
total the cost for each move
next
return

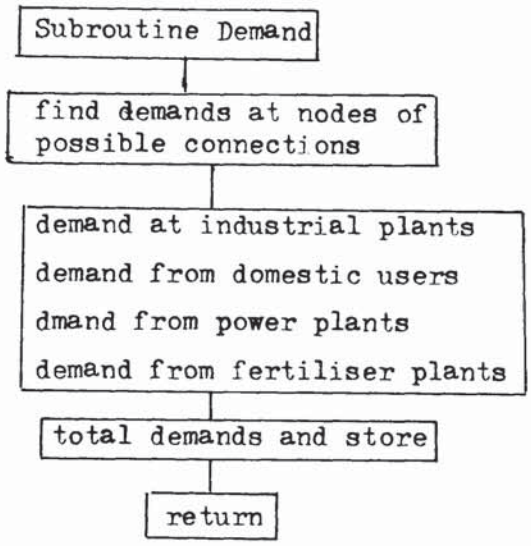

Subroutine Optimise
do 1 to n moves
does release =0
or no decsion
find cost for this move
to the end state
is this the
smallest cost so
far
Y
store cost
and state in
temporary array
N
next
store the smallest cost
to the end and state
return

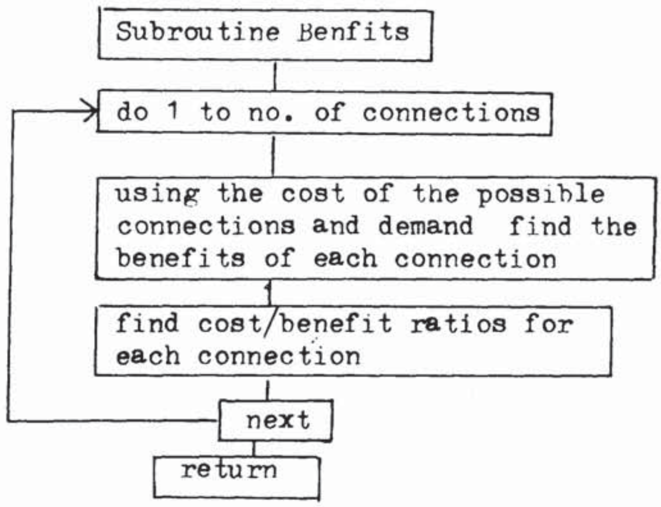
APPENDIX F GAS SIMULATION FLOWCHART

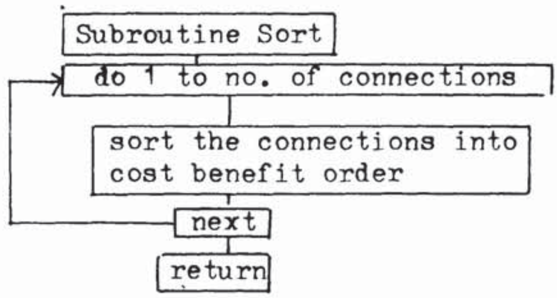





Subroutine Stage Connect
do 1 to no. of possible pipe connections
find all possible connections that can be made with the investment
next
return


Subroutine Demand
find demands at nodes of possible connections
demand at industrial plants
demand from domestic users
dmand from power plants
demand from fertiliser plants
total demands and store
return


Subroutine Benfits
do 1 to no. of connections
using the cost of the possible connections and demand find the benefits of each connection
find cost/benefit ratios for each connection
next
return


Subroutine Sort
do 1 to no. of connections
sort the connections into cost benefit order
next
return

APPENDIX G - TRAINING SURVEY

INTRODUCTION

Halcrow Water Company have been promoting the use of microcomputers in their work for three years or more. Although several overseas projects had made use of microcomputers, the majority of employees had not had a chance to use them and were unfamiliar with microcomputer applications. The Water Company decided to invest in a training course, run by an university, in order to familiarise employees with the use of microcomputers. The training course consisted of a familiarisation session with microcomputers, a review of CP/M and programming languages, then a more detailed look at three microcomputer packages, viz., Supercalc, Dbase II and Wordstar. The course was run for 8 people in one day. Each student was provided with a microcomputer for the day in order to facilitate full 'hands on' training. A questionnaire was designed and sent to each of the Halcrow employees in order to try to ascertain the worth of the course, (Hall,1984).

RESULTS FROM THE QUESTIONNAIRE

60 questionnaires were distributed of which 45 responses were received, giving a 75% response. 71% of the response had used computers of some form prior to the course, 29% had not previously used computers of any kind. 6 respondents had their own home computers and only 15 had used microcomputers prior to the course.

69% of the respondents felt that enough time had been spent on the computer familiarisation. This result was further analysed to examine whether those who had not previously used a computer disagreed with this majority result. Table G.1 shows the analysis.

The majority of the respondents found the section on programming languages understandable, relevant and useful but also found it too long.

Table G.1 Analysis of Course Time Spent on Computer Familiarisation.

	used computer before	not used a computer before
enough time spent	25	7
not enough time spent	6	7

The analysis of the results for the attitudes towards the sessions on CP/M, Supercalc, Dbase II and Wordstar are given in table G.2, they have been divided into those who had not previously used computers and those who had.

Table G.2 The Effect of Previous Computer Knowledge on Attitudes to the Course.

		CP/M	SUPERCALC	DBASE II	WORDSTAR
NOT	a	0	1	1	1
USED	b	5	2	1	2
COMPUTERS	c	4	8	7	4
BEFORE	d	3	1	3	5
HAD	a	2	1	2	5
USED	b	11	19	2	3
COMPUTERS	c	11	12	24	18
BEFORE	d	8	0	4	6

(1 respondent did not answer these questions)

a= too slow
b= just right
c= too fast
d= can't remember

The survey included several questions on course evaluation. 3 respondents thought the course too simple, 31 thought the course just right, whilst 10 found it too difficult. 6 respondents thought the course too specific, 25 said it was just right but 13 found it too generalised. The respondents were asked whether they felt one day had been long enough, but the results showed that 30 against 15 disagreed.

93% of the respondents thought the course was relevant to Halcrow work, but the rest felt it could have been more biased towards the type of work they actually do.

The survey next asked whether the course had changed the respondent's attitude towards microcomputers and asked for their reasons to their answers. 26 respondents said the course had not changed their attitudes. Of those 16 said they already recognised the benefits of the microcomputer. 9 did not give their reasons. Of those 18 respondents who said their attitudes had been changed, 15 suggested that the course had made them more aware of the benefits and the ease of using a microcomputer, but 3 did not give their reasons. The overall result, therefore, was very positive.

The respondents were asked whether they had used various packages since the course. The results are given below:-

19 have used Supercalc

8 have used Dbase II

8 have used Wordstar

7 have used MBASIC

2 have used FORTRAN 80

Only 35% of the respondents had used the self-teaching discs. 40% claim to have read the text to go with the discs. Only 20% completed the self-teaching discs. However, 29 respondants had read 'Managing with Micros' of which 83% said it had been relevant.

All respondents saw a future for microcomputers in Halcrow. Interestingly, all those who had not used computers prior to the course were not making use of micros afterwards.

ANALYSIS OF RESULTS AND COMMENTS

The section on programming languages was unpopular since it only touched upon languages on the microcomputer. Most felt that although it was useful, too much time was spent on only scratching the surface of this topic. It can be seen from Table G.2 that although the majority of respondents found the CP/M session either too fast or just right there seems to be no split in difference of opinion by previous non-users and users.

The results from the session on Supercalc suggest that it had been more easily understood by those who had previously used computers. 19 felt it was set at just the right speed, whereas the majority, (8) of the non-users found it too fast. The Supercalc package is one of the easiest commercial packages to learn on the microcomputer. The ease of Supercalc is reflected in the number of respondents who have used it since the course (42%) as compared with other packages.

The overall impression of Dbase II and Wordstar was that they were dealt with too quickly and the respondents were not gleaning very much from the sessions. Dbase II is a complex package and demands at least 2-3 hours to begin to understand its concepts, how to use it and to begin to identify applications. It seems that the rushed nature with which DBASE and Wordstar are taught is reflected in the amount of attention they have received since the courses. MBASIC and FORTRAN are not covered in any depth on the course and have been used even less.

Originally the self teaching discs were problematic and difficult to use, which may be the reason for such a small percentage of the respondents actually using them.

The respondents all saw a future for microcomputers in Halcrow which was encouraging, yet relatively few are making any use of them. Several reasons could exist for there lack of use, such as:

- did the course show their usefulness enough?
- are the machines available to be used?
- are project directors not encouraging the use of micros?
- do they recognise their potential?
- do engineers feel that there is a use but they have not yet had the opportunity to use them?

CONCLUSIONS AND RECOMMENDATIONS

Basically, the course had been useful in making people aware of the use of microcomputers, and there were several claims that the course had given those who had been apprehensive, the confidence to approach and use the machines in the future.

Since those respondents who had not used computers before found the course a little fast, it may have been an advantage to split those from the respondents with some experience, so that the groups are made up entirely of one or the other.

Many respondents pointed out that there were problems and discrepancies with the course content, and these should be ironed out. Some test problems failed to work and demonstrators did not seem completely sure of their examples. There were also claims that demonstrators repeated some of what had been previously said.

There were many comments that engineers find it easier to relate to engineering lecturers and engineering problems. Simple separate command sheets for DBASE II, Supercalc and Wordstar would be useful. The self-teaching discs could include simple problems which relate to project work and which could be carried out and checked against the answer on disc.

The course would be improved by putting Dbase II and Wordstar at an earlier part of the day or leaving them out entirely. These topics could then be dealt with in a follow-up course for those who had shown interest. The course would be usefully completed with a look at some technical applications which can be mounted on the microcomputer.

Some of the course is based on the students watching the demonstrator via overhead screens and following on the computer in front of them. There are difficulties in following a demonstration of this kind if the student falls behind or makes a mistake. The excercise often falls into a test whereby the student frantically tries to keep up with the input lines and take little notice of the actual content, so that little is learnt during the session.

It would be useful to have a training area within Burderop Park, where machines are permenantly kept and people can go to follow up the course.

In conclusion the results of the survey suggest that the training course has been a success and the majority of those employees who attended them found them to be of some benefit. It would be useful to send as many employees as possible onto a course of this kind in order to promote fully the use of the microcomputer. Also, a further course should be examined in order to cover further topics especially databases and an introduction to expert systems.

REFERENCES

Alcock, D.G. and Shearing, B.H. (1970)
"GENESYS - an attempt to rationalise the use of computers in structural engineering", The Structural Engineer, Vol.48, No.4, April 1970, pp143-152.

D'Agapeyeff, A. (1983)
"Expert systems, Fifth generation and UK suppliers", The National Computing Centre Limited, 1982.

L'Aguilar (1984)
" Cost Benefit of Microcomputers for the Consulting Engineer", Proc. of the Int. Conf. on Civil and Structural Engineering Software and Applications for Micro and Mini Computers, 1983, pp1-4.

Alvey Committee.(1984)
"A programme for advanced information technology : the report of the Alvey Committee", Department of Industry, 1982.

Bellman, R. (1957)
"Dynamic Programming", Princeton University Press, New Jersey, USA, (1957).

Bland, R.L. (1975)
"Engineers and Computers - Interaction or Reaction", Engineering Issues, Jou. of Prof. Activities of ASCE, Vol.101, No.EI2, April 1975, pp79-91.

Boehm, B.W. (1975)
"The high cost of software", Practical Strategies for Developing Large Software Systems, E.Horowitz (Ed.), Addison-Wesley, 1975, pp3-14.

Borrell, J. (1982)
"Printers: The Industry, Technology, and Markets", Digital Design, December 1982, pp36-45.

Bowles, J.E. (1981)
"Is the Computer Program giving Correct Answers?", Civil Engineering - ASCE, October 1981, pp59-61.

Brentano, L.D. (1978)
"Computers in a Civil Engineering Office", Proc. of Conf. on Computing in Civil Engineering, Atlanta, Georgia, USA, June 1978, pp37-52.

Britten, B. (1982)
"Winchesters on the Right Track", Computer Systems, December 1982, pp39-40.

Buras, N. (1966)
"Dynamic Programming in Water Resources Development", in Advances in Hydroscience, Vol.3 - V.T.Chow (Ed.), Academic Press, New York, USA, 1966, pp376-412.

Butcher, W.S. (1968)
"Mathematical Models for Optimising the Allocation of Stored Water", 'The Use of Analog and Digital Compters in Hydrology', Inter. Assoc. Scientific Hydrology, Tuscon, USA, December 1968.

Callcott, A. (1982)
"Hardware Report", Internal Report, Sir William Halcrow and Partners, 1982.

Cane, A. (1984)
"Flat Screens - Key to Portable Computers", Financial Times, 7th March 1984.

Chidley, T.R.E.C and J.Elgy (1984)
"Low cost image processing - The future prospects in Developing Countries", Colloquium on the Role of Microcomputers in Hydraulic Research and Education, IHE, Delft, the Netherlands, June 1984.

Chow, V.T., D.R.Maidment and G.W.Tauxe (1975)
"Computer Time and Memory Requirments for DP and DDDP in Water Resources Systems Analysis", Water Resorces Research, Vol.11, No.5, 1975, pp621-628.

Collofello, J.S., S.W.Woodfield and N.E.Gibbs (1982)
"Software Productivity Measurement", AFIPS - Conf. Proc. Vol.51, 1982, pp757-762.

Cornell, A.H. (1980)
'The Decision Makers Handbook', Prentice-Hall Inc., New Jersey, USA, 1980.

Creative Strategies International (1981)
"Microcomputer Software Strategies", Business Report, May 1981.

Crozier-Brown, J. (1978)
"Computers in Civil Engineering - An Overview", Proc. on Conf. of Computing in Civil Engineering, Atlanta, Georgia, USA, June 1978, pp1-11.

deNeufville, R and J.H.Stafford (1971)
'Systems Analysis for Engineers and Managers', McGraw-Hill Book Company (UK) Ltd., London, 1971.

The Economist (1983a)
"An Old Chip-making Process bids for a new lease of life", July 2th, 1983, p83-84.

The Economist (1983b)
"Customised semiconductor materials are on their way", July 16th, 1983, p75.

Fenves, S.J. (1982)
"Computers in civil engineering Practice", Jou. of the Technical Council of ASCE, Vol.108, No.TC1, May 1982, pp44-52.

Fenves, S.J. and R.L.Schiffman (1979)
"Quality Assurance of Engineering Software", Jou. of the Technical Council of ASCE, Vol. , No.TC1, April 1979, pp57-74.

Gal, S. (1979)
"Optimal Management of a Multi-reservoir water supply system", Water Resources Research, Vol.15, No.4, August 1979, pp737-749.

Garrett, M.F. (1982)
"Computet-aided drafting in civil engineering", Civil Engineering - ASCE, May 1982, pp72-78.

Hall,M.J. (1984)
"In-house and counterpart training on microcomputers for Civil Engineering Consultancy", Colloquium on the Role of Microcomputers in Hydraulic Research and Education, IHE, Delft, the Netherlands, June 1984.

Hall, W.A., W.S.Butcher and A.S.Esogbue (1968)
"Optimisation of the operation of a multiple purpose reservoir by Dynamic Programming", Water Resources Research, Vol.4, No.3, June 1968, pp471-478.

Hall, W.A. and J.A.Dracup (1970)
"Water Resources Systems Engineering", McGraw-Hill Series in Water Resources and Environmental Engineering, 1970.

Hall, W.A. 1964

"Optimum design of a multiple purpose reservoir", Jou. of Hydraulics Div., ASCE, No.HY4, July 1964, pp141-149.

Heering, J. (1980)

"The Intel 8086, the Zilog Z8000 and the MC68000 Microprocessors", Euromicro Journal 6 (1980), pp135-143.

Heidari, M., V.T.Chow, P.V.Kokotovic and D.D.Meredith (1971)

"Discrete Differntial Dynamic programming approach to water resources systems optimisation", Water Resources Research, Vol.7, No.2, April 1971, pp273-282.

Heintz, C. (1983)

"Guide to database system software", Interface Age, Vol.8, No.2, February 1983, pp52-66.

Hemenway, J. (1981)

"Microcomputer Operating system comes of age", Mini-Micro systems (USA), Vol.13, No.10, October 1981, pp97-98, pp103-112, pp114-119.

Hiessl,H. and E.J.Plate (1983)

"Optimal control of irrigation systems with distributed water demand", Internatinal Association of Hydrological Sciences Symposium, Hamburg, August 22-23 1983.

Holbrooke, R. (1982),

Personal Communication, Sir wiliam Halcrow and Partners, 1983.

Huffman, G. (1980)

"As UC-System complexity grows support chips assume host tasks", EDN (USA), 5th November 1980, pp152-198.

Johnson, W.K. (1972)
"Use of systems analysis in water resources planning", Jou. of Hydraulics Div., ASCE, Vol.96, No.HY6, 1972, pp1543-1556

Johnson, K.H. (1981)
"Micro/Desktop computers: Applications and Selection", Proc. of the Int. Conf. on computing in Civil Engineering, (N.Y)(ASCE),1981, pp121-133.

Lipetz, M.B. (1978)
"Considerations in the aquistion of a computer", Proc. on Conf. Computing in civil engineering, Atlanta, Georgia, June 1978, pp229-241.

Lustman, F., P.Lanthier, D.Charbonneau et al (1978)
"A systemmatic approach to choosing a computer", Canadian Datasystems, April 1978, pp354-358.

McCool, J. (1980)
"Microcomputers in Design", The Consulting Engineer (GB), Vol.44, No.7, July 1980, pp37-39.

Males, R.M. (1982)
"Computer applications in water resources planning", Jou. of the Technical Council of ASCE, Vol.108, No.TC1, May 1982, pp

Middelboe, S. (1984)
"Carpark Report slams design check", New Civil Engineer, 5th January 1984, p4.

Neale, R.H. and J.N.Boland (1980)
"Research into the application of small computers to th design of scaffold falseworks", Instn. Civil Engineers, Part 1, Vol.68, August 1980, pp463-476.

Nemhauser, G.L. (1966)
"Introduction to Dynamic Programming", John Wiley & Sons Inc., 1966.

Phillips, C. (1983)
"A standard 16 bit O/S?", Computer systems, August 1983, pp33-39.

Pountain, D. (1983)
"Benchmarks Summary", Personal Computer World, 1983, pp110-111, 214.

Powys-Lybbe, D. (1981)
"CP/M Operating System - the Software Bus", Microprocessors and Microcomputers, Vol.5, no.3, April 1981, pp115-117.

Prior, M. (1983)
Personal Communication, Sir William Halcrow and Partners, 1983.

Rundle, T. (1983)
"Will the real UNIX please stand up?", Computer systems, October 1983, pp49-56.

Saal, H.J. (1981)
"Local-area networks - Possibilities for personal computers", BYTE, October 1981, pp92-111.

Schwartz, J. (1975)
"Construction of software: problems and practicalities", Practical Strategies for developing large software systems, 1975, pp15-33.

Schiffman, R.L. and E.R. Krueger, (1972)
"Computer use in civil engineering", Engineering Issues - Jou. of Prof. Activities, ASCE, Vol. , No. , April 1970, pp251-271.

Schmidt, O. and E.J.Plate (1983)
"Optimisation of reservoir operation for irrigation and determination of the optimum size of irrigation area", International Association of Hydrological Sciences Symposium, Hamburg, August 22-23 1983.

Scofield, J. (1983)
"IBM-XT", Practical Computing, August 1983, pp130-131.

Shelley, J. (1981)
"Microcfuture", Pitman Education Ltd., 1981.

Sommerville, I. (1982)
"Software Engineering", Addisson-Wesley Publishing Company, 1982.

Spencer, R. (1983)
"The significance of the 432", Computer systems, April 1983, p47-50.

Sutton, D.A. (1983)
"The challenge of Hard-disk portability", BYTE, September 1983, pp127-134.

Taffs, D. (1981)
"Use of computers by UK consulting Engineers", Proc. of Int. Conf. on Computing in Civil Engineering (NY)(ASCE), 1981, pp702-713.

Taffs, D. (1983)
"Recent and future developments in the role of microcomputers in the design office", Proc. of the Int. Conf. on Civil and Structural Engineering Software and Applications for Micro and Mini Computers, pp1-3.

Tyler, G. (1983)
"The Shrinking Drive", Computer systems, March 1983, pp67-69.

Watson, C.E. and C.P. Felix (1977)

"A method of programming measurement and estimation", IBM Systems Journal, 1977, pp54-73.

Wise, K.D., K. Chew and R.E. Yokely (1980)

'Microcomputers - A technology Forecast ans assessment to the year 2000', Wiley and sons, 1980.

Wszola, S.J. (1983)

"Computing on the run", BYTE, September, 1983, pp33-45.

BIBLIOGRAPHY

Gane, C. and T.Sarson, "Structured Systems Analysis Tools and Techniques", Prentice-Hall, 1979.

Feigenbaum, E.A and P.McCorduck, "The Fifth Generation", Pan Books, 1984.

Sobhan, R. "The Crisis of External Dependance", University Press (Dhaka), 1982.

Zaks, R. "Microprocessors", Sybex Inc. 1980