

**Information Systems Applications In Regional Planning
(Trends, Issues, And Problems In Developing Countries)**

By

Jerry C Coiner

Information Systems Applications in Regional Planning
(Trends, Issues, and Problems in Developing Countries)

by

Jerry C. Coiner, Ph.D.
Remote Sensing & Information Systems Co.
Kailua-Kona, Hawaii, U.S.A.

September 1, 1988

Prepared for the United Nations Centre for Regional Development,
Expert Group Meeting on Integrating Information Systems/Informa-
tion Technology in Local/Regional Development Planning, held in
Singapore, 31 October - 4 November 1988

This report has not been approved by the United Nations Centre
for Regional Development, which does not necessarily share the
views expressed.

Information Systems Applications in Regional Planning
(Trends, Issues, and Problems in Developing Countries)

ABSTRACT/SUMMARY

Three major classes of information systems/information technology are being introduced into planning agencies in development countries. at the same time -- microcomputers, minicomputers and mainframes. Review of each of those technologies and their applications illustrates that microcomputers most directly impact individual planners, while minicomputers serve projects and agencies, and mainframes encompass large institutions.

Experience with information systems in developing countries has been based mainly on microcomputer applications, with heavy emphasis on commercial word processing, spreadsheet and data base management applications. As more advanced microcomputers become available in developing countries, new applications in project management, desk top publishing, and computer-aided design and drafting will be of great utility to planning agencies. The availability of specially-designed applications to meet the needs of development planning is still extremely limited.

Minicomputers offer a wide variety of potentially-powerful, project-level planning tools, including geographic information systems and remote sensing data analysis. Minicomputers introduce into planning agencies the need for professional information systems staffing and for a planned approach to using computers.

Mainframes are usually shared information resources that require extensive external support. They are useful in large-scale modeling and simulation and in the development of inter-agency information systems. Because of the need for complex technical skills often not available in developing countries, mainframe approaches to information systems are more prone to fail than either microcomputer or minicomputer applications.

The key to successful transfer of information systems and information technology is how the application is implemented in the new environment. Five guidelines are proposed to assist in successful implementation.

1. Plan the system for incremental introduction.
2. Design toward the least-complex configuration with local support.
3. Use longer lead times for installation of the system.
4. Approach cautiously the direct transfer of applications.
5. Train end users and other staff how to use the system and make clear its purpose.

Information systems will not alone solve development planning problems, but if properly implemented and used, the systems can provide better information on which to base plans and development decisions.

TABLE OF CONTENTS

1.	Introduction.....	1
1.1.	Planning Environment.....	1
1.2.	Background.....	1
1.3.	Computers in Planning.....	2
1.4.	Purpose.....	2
1.5.	Organization.....	2
1.6.	Perspective.....	3
2.	Microcomputers (Individual Planner).....	4
2.1.	Hardware.....	4
2.1.1.	Standard Configuration.....	4
2.1.1.1.	IBM PC/PC XT or PC Clone.....	4
2.1.1.2.	IBM PC AT or AT Clone.....	5
2.1.1.3.	Intel 386 Machines.....	5
2.1.1.4.	Personal System 2 (PS/2).....	5
2.1.2.	Apple Computer Family.....	5
2.1.2.1.	Apple II.....	5
2.1.2.2.	Macintosh.....	6
2.1.2.3.	Macintosh II.....	6
2.1.3.	Other Systems.....	6
2.1.4.	Laptop Computers.....	6
2.1.5.	Peripherals and Add Ons.....	7
2.1.6.	Problem Areas.....	7
2.1.6.1.	Technical.....	7
2.1.6.2.	Organizational.....	7
2.1.6.3.	Operational.....	8
2.1.7.	Trends.....	8
2.1.7.1.	Availability.....	8
2.1.7.2.	Graphics Capability.....	9
2.2.	Operating Systems.....	9
2.2.1.	MS-DOS/PC DOS.....	9
2.2.2.	OS/2.....	10
2.2.3.	Apple Computer Operating Systems.....	10
2.2.4.	Other Operating Systems.....	10
2.2.5.	Problem Areas.....	10
2.2.5.1.	Technical.....	11
2.2.5.2.	Organizational.....	11
2.2.5.3.	Operational.....	11
2.2.6.	Trends.....	12
2.2.6.1.	OS/2.....	12
2.2.6.2.	UNIX.....	12

TABLE OF CONTENTS (Continued)

2.3.	Programming Languages.....	13
2.3.1.	Sequential Languages.....	13
2.3.1.1.	BASIC.....	13
2.3.1.2.	Fortran.....	14
2.3.1.3.	COBOL.....	14
2.3.1.4.	Limits of Non-Structured Languages.....	14
2.3.2.	Structured Languages.....	14
2.3.2.1.	Pascal.....	15
2.3.2.2.	C.....	15
2.3.2.3.	Limits of Structured Languages.....	15
2.3.3.	Other Programming Languages.....	15
2.3.3.1.	Object-Oriented Programming Languages.....	16
2.3.3.2.	Fourth Generation Languages.....	16
2.3.3.3.	Artificial Intelligence Languages.....	16
2.3.4.	Problem Areas.....	16
2.3.4.1.	Technical.....	17
2.3.4.2.	Organizational.....	17
2.3.4.3.	Operational.....	17
2.3.5.	Trends.....	17
2.3.5.1.	Specialized Languages.....	17
2.3.5.2.	Programming Environments.....	18
2.4.	Applications Software.....	18
2.4.1.	First Generation Applications Software.....	19
2.4.1.1.	Word Processing.....	19
2.4.1.2.	Spreadsheets.....	21
2.4.1.3.	Data Base Management System (DBMS).....	23
2.4.1.4.	Communications Software.....	25
2.4.2.	Second Generation Applications.....	26
2.4.2.1.	Project Management.....	26
2.4.2.2.	Desk-Top Publishing.....	27
2.4.2.3.	Computer-Aided Design and Drafting (CADD).....	28
2.5.	Planning Applications.....	30
2.5.1.	Custom Planning Applications.....	30
2.5.1.1.	BASIC Microcomputer Programs for Urban Analysis and Planning.....	31
2.5.1.2.	FIVFIV-SINSIN.....	31
2.5.1.3.	PLACE.....	31
2.5.1.4.	Urban Data Management Software (UDMS).....	31
2.5.2.	Templates.....	32
2.5.3.	Problems.....	32
2.5.3.1.	Technical.....	32
2.5.3.2.	Organizational.....	33
2.5.3.3.	Operational.....	33
2.5.4.	Trends.....	33

TABLE OF CONTENTS (Continued)

3.	Minicomputers, Super Microcomputers and LANs --	
	Regional Planning Projects.....	34
3.1.	Super Microcomputers (Supermicros).....	34
3.1.1.	Hardware.....	34
3.1.2.	Operating System.....	35
3.1.3.	Programming Languages.....	35
3.1.4.	Applications Software.....	35
3.1.4.1.	Data Base Management Systems (DBMS).....	35
3.1.4.2.	Other Applications.....	35
3.1.5.	Problems.....	36
3.1.5.1.	Technical.....	36
3.1.5.2.	Organizational.....	36
3.1.5.3.	Operational.....	36
3.1.6.	Trends.....	37
3.2.	Local Area Network (LAN).....	37
3.2.1.	Hardware.....	37
3.2.2.	Operating System.....	38
3.2.3.	Programming Languages.....	38
3.2.4.	Applications Software.....	38
3.2.5.	Problems.....	38
3.2.5.1.	Technical.....	39
3.2.5.2.	Organizational.....	39
3.2.5.3.	Operational.....	39
3.2.6.	Trends.....	39
3.3.	Minicomputers.....	40
3.3.1.	Hardware.....	40
3.3.2.	Operating Systems.....	41
3.3.3.	Programming Languages.....	42
3.3.4.	Applications.....	42
3.3.4.1.	DBMS.....	42
3.3.4.2.	Geographic Information Systems (GIS).....	42
3.3.4.3.	Remote Sensing Image Analysis.....	43
3.3.5.	Problems.....	44
3.3.5.1.	Technical (Hardware).....	44
3.3.5.2.	Technical (Software).....	44
3.3.5.3.	Organizational.....	45
3.3.5.4.	Operational.....	45
3.3.6.	Trends.....	46
4.	Mainframe Computers -- Regional Planning	
	Organizations.....	47
4.1.	Hardware.....	47
4.2.	Systems Network Concepts.....	48
4.3.	Operating Systems (OSs).....	48
4.4.	Programming Languages.....	48
4.5.	Applications.....	49

TABLE OF CONTENTS (Continued)

4.6.	Problems.....	50
4.6.1.	Technical.....	51
4.6.2.	Organizational.....	51
4.6.3.	Operational.....	52
4.7.	Trends.....	52
5.	Systems Implementation.....	54
5.1.	Guidelines.....	54
5.1.1.	Incremental Introduction.....	54
5.1.2.	Least-Complex Configuration.....	54
5.1.3.	Longer Lead Times.....	55
5.1.4.	Direct Transfer of Applications.....	55
5.1.5.	Training.....	55
5.2.	Choices.....	56
6.	Bibliography.....	57

1. Introduction.

Profound changes in the way societies organize and administer their affairs have taken place in the last forty years. No longer do a few major powers dominate governance or dictate methods of administration. During the same period, the driving technological force in society has shifted from the production of goods (industrialization) to the processing of information -- the second industrial or information revolution. The initial impact and benefits of this information revolution have been largely concentrated in developed, Northern countries. In those countries, information technology and information systems have had as large an impact on public administration as they have had on the private sector. Planning has not escaped change. The newly-independent countries of the South must now determine what role information technology/information systems will play in the planning and development of their societies. This study reviews information technology/information systems and presents examples of their use in development planning. The intent of the report is to assist developing-country planners faced with choosing information technology/information systems to make informed choices of appropriate technology.

1.1. Planning Environment. Use of computers in regional planning is largely controlled by the environment in which planning takes place. In both developed and developing countries, regional planning is an activity largely undertaken by government organizations at the metropolitan, provincial and national levels. It is this governmental/administrative environment that establishes the role that computing plays in regional planning and determines to a large extent the types of computer applications and speed of their introduction. In developing countries, the nature and capability of public administration varies widely from country to country and from level to level within countries. This diversity in the competence of public administration is closely paralleled by the wide-ranging differences in the effectiveness of computer applications among developing countries and even within the same country.

1.2. Background. The idea of using computers to support regional planning in developing countries was first seriously considered in the 1970s, when mainframe computer technology was diffused. Major computer applications impacting regional planning in developing countries were: the worldwide projects of the United Nations Fund for Population Activities (UNFPA) and the United States Bureau of the Census. Those development projects were undertaken to improve the census-taking and analysis capabilities of various developing-country governments. As a side benefit, the projects led to the introduction of computers into substantive data collection and analysis which had direct bearing on the governments' regional planning capabilities. However, use

of computers did not expand rapidly from those early demographic applications into governments' planning agencies. Undoubtedly, the causes stemmed from bureaucratic and technical problems related to the use of mainframe computers in developing-country environments.

1.3. Computers in Planning. Widespread regional planning applications had to await the microcomputer revolution of the late 1970s and early 1980s. By 1980, multilateral and bilateral donor agencies had become sensitized to the potential of microcomputers as development and regional planning tools. Early regional planning applications were developed by the United Nations Centre for Human Settlements (UNCHS-Habitat) and were made available to planning organizations in developing countries. However, it was largely administrative applications, such as word processing and spreadsheeting for budgets, which first gained acceptance. Only in the last five years has more attention been paid to using computing as a tool in the substantive aspects of planning.

1.4. Purpose. The purpose of this report is to review the state-of-the-art of computer applications for regional planning in developing countries. In the context of this review, a systems integration view of computer applications will be taken, with both the physical (hardware and software) and organizational (applications and personnel) aspects subject to analysis. Emphasis will be placed on applications that are currently employed by planning organizations in developing countries.

1.5. Organization. This report is organized into three major sections. Each section considers a different type of computer system (microcomputer, minicomputer, and mainframe) and shows how the system relates to a different level or scope of activity within regional planning. Microcomputers are discussed in terms of personal productivity tools or workstations for the individual planner. Minicomputers, super-microcomputers, and local area networks (LANs) are presented as systems to support regional planning projects with multi-user data bases and/or geographic information systems. Mainframe computers are defined in terms of providing computing resources to an entire planning organization, with applications that include administrative functions (such as development control) as well as substantive planning tasks.

1.5.1. The three sections incorporate information on the following topics - hardware and software configurations used in regional planning, and regional planning applications both currently operational and under development. Additional materials are included on problems with the systems when they are used in developing countries. Those problems are discussed in terms of technical, organizational and operational problems. Also, future trends in hardware and software applications are presented.

1.5.2. A fourth section contains an analysis of the implementation of computer systems in developing countries, that is, the process of defining, installing, and making operational computer systems which are selected. The section identifies problem areas and presents some guidelines which may reduce problems that are encountered when computers are introduced into planning organizations. Finally, a bibliography of materials for further reading is presented.

1.6. Perspective. In the 1980s, thousands of computer applications to support regional planning were developed and installed on all types of computer systems throughout the world. Many were not documented or reported in the literature of either computing or regional planning. Therefore, examples of systems implementation and operation used in this report represent only those that have come to the attention of the author through the literature or the author's own consulting activities. This perspective does not represent an unbiased sample by any definition of the term.

2. Microcomputers (Individual Planner).

The advent of the microprocessor in the mid-1970s made possible the development of micro- or personal computers (PCs). Those machines, with their relatively low cost and wide availability, have become the major computing resource in most developing-country planning offices. In the late 1980s, the personal computer matured into the workstation concept. The workstation can be viewed as the individual planner's tool box: the PCs' resident software applications can be combined with networking and gateway links to provide access to project and institutional-level data bases and applications. PCs configured as workstations, especially those with graphics capabilities, are just beginning to enter developing-country planning offices.

2.1. Hardware. There is a wide variety of microcomputer hardware in service in developing-country regional planning agencies. The majority of those systems are IBM PC, XT or AT microcomputers or machines that operate the same way and use the same software. Those IBM run-alike machines are known as "clones." However, there are also Apple computers and earlier eight-bit CP/M systems. Generally, planning agencies in developing countries will have a smaller number, but wider array, of hardware types and configurations than would be the case in a developed-country planning office. Their eclectic hardware suites are the result of hardware purchased under donor-funded projects or grants and the general lack of a plan for the introduction and use of computer technology within the organization.

2.1.1. Standard Configuration. The majority of regional planning organizations in developing countries will have access to, as a minimum, a single IBM PC or clone. More likely, the office will have two or three individual machines, usually of the PC or PC XT type but with additional PC AT machines or AT clones being brought into use.

2.1.1.1. IBM PC/PC XT or PC Clone. This most common of hardware configurations consists of an IBM PC or PC XT or run-alike PC clone with an Intel 8088 or 8086 microprocessor, 256 to 640 Kilobytes (Kbytes) of random access memory (RAM), two 360 Kbyte 5.25 inch dual-sided, dual-density disk drives, monochrome monitor and adapter, and parallel/serial communications capability. If the system is an IBM PC XT, one of the 360 Kbyte disk drives will be replaced with a 10 or 20 Megabyte (Mbyte) fixed disk. About one-third of the systems will have a color graphics adapter and/or Intel 8087 math coprocessor. The most common peripheral device is a parallel-interfaced, dot matrix printer with 100 to 200 characters per second (CPS) draft mode and 25 CPS near-letter quality (NLQ) mode. A significant minority of the printers are of the impact type (print appears typewritten). Some of the early PC systems have been field

upgraded with the installation of 20 Mbyte fixed disks. Rarely do the systems have communications capabilities, either in terms of modems or an intraorganizational LAN.

2.1.1.2. IBM PC AT or AT Clone. Since 1985, planning organizations have normally purchased the more powerful IBM PC AT or run-alike AT clones. The standard configuration is an Intel 80286 microprocessor, 640 Kbytes RAM, one 1.2 Mbyte 5.25 inch dual-sided, quad-density disk drive, one 30 Mbyte fixed disk, monochrome monitor and adapter, and serial/parallel communications. A significant number of those machines will be upgraded with the Intel 80287 math coprocessor, enhanced graphics adapter, and color monitor for use as low-end graphics workstations. The systems will normally be equipped with dot matrix printers, or, if used for report generation, with an impact printer. As with the more common PC and PC XT type machines, the systems are used as stand-alone workstations.

2.1.1.3. Intel 386 Machines. Although few of the Intel 80386-based microcomputers have entered service in developing-country planning agencies, the machines are used as graphics workstations and file servers in LANs. The standard configuration is an Intel 80386 microprocessor, 80287 math coprocessor, one to two Mbytes RAM, one 1.2 Mbyte 5.25 inch dual-sided, quad-density disk drive, one 40 Mbyte fixed disk, color monitor and enhanced graphics adapter, and serial/parallel communications. For the graphics workstation configuration, peripherals include a digitizer, plotter, and matrix printer. When the 386 machines are used as file servers for a LAN, the fixed-disk capacity is usually increased to a minimum of 80 Mbytes.

2.1.1.4. Personal System 2 (PS/2). In 1987, IBM released a new family of microcomputers known as the PS/2. The machines, which feature new internal microbus architecture, replace the PC, PC XT, and PC AT and add new Intel 80386-based machines, the PS/2 Models 70 and 80. Whether those machines will replace the existing microcomputer standard, based on the original PC line, is not clear. PS/2s offer only marginal enhancement of capability over the original PC series and are not totally compatible with them because of the introduction of 3.5 inch 700 Kbyte and 1.4 Mbyte disk drives as standard equipment. Several other manufacturers are preparing compatible systems which use IBM's PS/2 microbus architecture.

2.1.2. Apple Computer Family. A number of planning agencies also have Apple computers instead of or in addition to the IBM PCs or clones. The machines may be Apple IIs or Macintoshes. Frequently, they were acquired for a specific donor's application and may not be used to meet other computing requirements of the agency.

2.1.2.1. Apple II. The most commonly-found Apple computer is the Apple II. There are a number of models -- Apple IIe, Apple IIc, and Apple IIgs. Those systems are normally configured with the 85C02 or 85C816 microprocessor, 64 to 256 Kbytes RAM, either

one 143 Kbyte 5.25 inch single-sided, single-density disk drive or one 800 Kbyte 3.5 inch dual-sided, dual-density disk drive (IIGS only). The systems will interface to either monochrome or color monitors. Usually, a matrix printer is attached to the system.

2.1.2.2. Macintosh. More Apple Macintosh systems have been used since 1986 than previously in regional planning offices. There are two models, the Macintosh Plus and Macintosh SE. The standard configuration is an MC68000 microprocessor, one Mbyte RAM, one 800 Kbyte 3.5 inch dual-sided, dual-density disk drive, one 20 Mbyte hard disk (SE), a nine inch high resolution monochrome monitor, and a mouse (screen pointing device). Usually, a matrix printer is attached, but a laser printer is available for use in desk-top publishing applications.

2.1.2.3. Macintosh II. The Macintosh II is the most-recently released Apple computer. Although few have yet found their way into developing-country regional planning offices, the Macintosh II may be the low-cost graphics workstation needed to bring graphics-based planning applications into wider use. The system is configured with a MC68020 microprocessor, a 68881 math coprocessor, one Mbyte RAM, one 800 Kbyte 3.5 inch dual-sided, dual-density disk drive, one 40 Mbyte hard disk, a monochrome or color monitor, and a mouse (screen pointing device). The system can support matrix, impact or laser printers and other graphics input/output devices, such as digitizers and plotters.

2.1.3. Other Systems. Prior to the emergence of the IBM PC standard in 1983, there were a large number of different microcomputer systems being purchased by regional planning agencies. Usually, the systems were eight bit (Z-80 or 8080 microprocessors) microcomputers using the CP/M operating system. Much of this hardware is still operational for the limited applications that were developed at the time; however, those systems would be difficult to combine with a LAN or to use as workstations in a hierarchical system with a minicomputer or mainframe. Essentially, they are useful only for their current applications and cannot be integrated into an overall organizational computer system.

2.1.4. Laptop Computers. Since 1985, portable laptop computers have been introduced into planning offices in developing countries. Other than portability, the machines offer a number of advantages, including battery operation, ruggedized construction, and software compatibility with existing IBM PC family machines. Several types of the machines are available with capabilities roughly parallel to those of the IBM PC, PC XT, PC AT and the Intel 386 systems. The major physical difference between laptops and standard desktop PCs is the replacement of the monochrome or color monitor with a flat monochrome liquid crystal display (LCD) or gas plasma display. Although laptop computers are not widely used by planning agencies in developing

countries, their battery operation and ruggedized construction make them more reliable than standard desktop microcomputers for many developing-country operating environments.

2.1.5. Peripherals and Add Ons. Aside from the matrix and impact printers already mentioned above, few peripheral devices or add-on capabilities are used with existing systems. Some organizations may have begun using pointing devices, such as a mouse, but only a handful of agencies have ventured into the realm of graphics devices, such as digitizers, plotters and high-resolution graphics monitors.

2.1.6. Problem Areas. Use of microcomputers in humid and arid tropical environments, which typify many developing countries, has led to a greater number of hardware failures than is common when employing microcomputers in developed countries. Many of the systems have been installed at sites with no power conditioning, which has caused shortened component lives due to power surges and outages. Also, most developing-country government planning organizations do not have the staff or cannot afford outside support for the routine preventive maintenance, which would increase systems' life expectancies.

2.1.6.1. Technical. Microcomputers are designed and manufactured by engineers who assume a set of environmental conditions for practical use of the machines similar to conditions they observe in their surroundings. This inherent design constraint assumes reliable power, limited and controlled temperature ranges, and dirt and dust-free work spaces. Many of those conditions are not routinely met in developing-country application sites. This leads to higher rates of component failure, due to continuing power surges and higher operating temperatures. Also, electromechanical components of the systems, such as disk drives and disks, tend to wear much faster due to ablation by dust. When systems are installed in these harsh environments, the systems must be buffered as much as possible. Power conditioners should be used and a clean environment maintained. If the systems are to be installed in areas of extreme power problems, some consideration should be given to using laptops vice standard desktop computers, because laptops can be isolated with batteries and are generally better ruggedized than their desktop counterparts.

2.1.6.2. Organizational. To date, introduction of microcomputers into regional planning agencies has been largely piecemeal. Emphasis has been on specific applications, with little thought given to the overall computing environment. Although the ultimate purpose of the microcomputer is to support an application or cluster of applications, without proper institutional support for maintenance, the hardware components of the system will fail and the whole application then ceases to function because of hardware problems. In many cases, regional planning agencies in developing countries have also failed to budget funds for maintenance contracts and supplies, such as diskettes and paper, which have often caused microcomputers to

sit idle when supplies are exhausted. If a microcomputer is introduced into an agency, more emphasis needs to be placed on identifying the person who will be responsible for the day-to-day care of the system, as well as local sources of maintenance and supplies. Sources for these services should be a major consideration in the choice of specific hardware in a given country.

2.1.6.3. . Operational. To date, the introduction of microcomputers in developing-country regional planning offices has been carried out chiefly with the assistance of foreign experts provided by multi- or bilateral donor agencies. Most of those experts are specialists in their field, e.g., regional planning, but lack computer systems backgrounds, especially in areas related to hardware selection and maintenance. Since the expert is responsible for the transfer of the application, emphasis is placed on the user interface with the program, and little emphasis is given to transferring knowledge about the hardware, which remains a closed black box. This leads to problems when the expert departs and the application must be sustained from local resources. When systems are introduced, more attention must be given not only to the transfer of the procedures to run and analyze outputs of the applications, but to the routine, day-to-day procedures of systems operation and preventive maintenance. Also, at least one staff member must be given some rudimentary training in systems maintenance. This is even true at sites where only one or two microcomputers are in operation.

2.1.7. Trends. The 1980s saw a rapid evolution of microprocessor technology, from the early eight bit Zilog Z-80 to the current generation 32-bit Intel 80386 and Motorola MC68000. With the introduction of 32-bit processors, computer designers are of the opinion that ample storage and processing are accessible for most general purpose computing needs now and in the foreseeable future. New advances can be expected to concentrate on increased processor speed and specialized processors that optimize a specific type of application, e.g., vector processing. Although prices of basic microcomputer systems may continue to decrease, powerful systems with computing and graphics capabilities required for modeling and simulating regional change will probably remain in their present range.

2.1.7.1. Availability. Generally, sources of microcomputers in developing countries have been limited to larger multinational computer firms, such as IBM, NCR and Wang. Local dealers and distributors for wider ranges of systems, especially the lower-cost clones, have been slow to develop, and many local dealers have not been able to support their installed systems base. Recently, independent, reliable dealers have become more common and have greatly increased the availability of hardware and the quality of support available. Major multinational computer companies have also begun to recognize the importance of developing-country markets and have started to emphasize the sale and support of microcomputers, especially for entry-level

computing. This trend toward widespread availability and good local support should continue as long as government import restrictions do not limit the number of systems and artificially cap market size below the economic threshold for independent computer dealers.

2.1.7.2. Graphics Capability. Since the landscape that is the basic subject of regional planning is three-dimensional reality, microcomputers must have the capability to display spatial information graphically and to produce thematic maps. Such capabilities have been limited by processor speed, RAM size, and available graphics adapters. With the introduction of 32-bit microcomputers, which operate a 20+ Megahertz (Mhz) clock time, support up to eight MBytes of RAM, and have new VGA graphics adapters, the hardware capability for graphical analysis is fully implemented. Continued improvement in the graphics support capability of microcomputers can be expected. Also, improved devices for the input and output of spatial data can be expected. The present generation of digitizers and plotters will be supplemented by vidicons and scanners that can encode maps quickly and efficiently. New plotters will be able to generate color maps and graphics. More importantly, the cost and reliability of graphics peripherals should be reduced, as greater demand for such devices is generated.

2.2. Operating Systems. Interposed between a computer system's built-in primitive instructions (firmware) and the applications software that interprets user commands into computer activity is the operating system. An operating system is the lowest level of computer software with which the user directly interacts. The function of the operating system is to process user commands and supervise the internal activity of the computer. At present, the predominant operating system used with the IBM PC family and its clones is various versions of Microsoft Disk Operating System, usually referred to as MS-DOS (if supplied by Microsoft) or PC DOS (if supplied by IBM). Other operating systems are used with Apple computers, and non-MS-DOS operating systems are available for the PC family and clones.

2.2.1. MS-DOS/PC DOS. MS-DOS was developed in the late 1970s and has been under continuous modification and improvement until the present. The latest version of MS-DOS is 3.3; however, earlier versions are still marketed and widely used. MS-DOS consists of the operating system's supervisory programs, which are loaded to memory (RAM) from disk when the computer is started (booted) or reset, and a set of utilities, which may be stored in RAM (resident) or loaded from disk as programs to assist in managing, formatting and copying disks, setting systems parameters, and automatically executing applications programs. Because MS-DOS' user interface is the command line, its commands are short code words (DIR, ERA, FORMAT). Many users find MS-DOS' user interface difficult and learn only those commands essential for the day-to-day operation of their specific applications. One of the main problems with existing versions of MS-DOS is its inability to take full advantage of the memory (RAM) available in the newer

Intel 80286- and 80386-based microcomputers. MS-DOS is limited to the direct management of 640 Kbytes of memory, while newer systems can be configured with up to 64 Mbytes of RAM. This has started a search for a replacement operating system which can fully use the capacity of new and more powerful microcomputers with their large memories. It is also common for various hardware manufacturers to modify MS-DOS utility programs and deliver different utilities than are available from Microsoft. That practice tends to reduce the universality of the MS-DOS commands and to require machine-specific DOS training.

2.2.2. OS/2. In 1987, IBM and Microsoft announced a replacement operating system for MS-DOS, known as "OS/2." This operating system was to provide full software access to the capabilities of the Intel 80286 family of microprocessors used in IBM's PS/2 microcomputers and allow upward migration of MS-DOS applications software to OS/2, plus support multitasking. OS/2 was released for general distribution in the spring of 1988 and is still in very limited use. Most installed PS/2 systems are currently operating under MS-DOS.

2.2.3. Apple Computer Operating Systems. Apple Computer has used a number of different operating systems with the Apple II family of computers. They include several versions of Apple DOS and ProDOS. Apple's operating systems are keyboard command driven and suffer from problems of user friendliness similar to those of MS-DOS. Apple's Macintosh line uses a proprietary operating system, known as "Macintosh System." This operating system is unique in allowing the user the choice of accessing the operating system's functions and utilities with the traditional command line or a mouse pointing device in conjunction with screen pictographic representations (icons) of the desired activity. This graphic approach to command selection and execution has greatly simplified user access to the operating system.

2.2.4. Other Operating Systems. Occasionally, other operating systems, such as various versions of Control Program Microprocessor (CP/M), will be encountered in developing-country environments. Essentially, CP/M is very similar to MS-DOS in its commands and functions. Other operating systems, such as UNIX, XENIX and Pick, are normally used with microcomputers in multi-user environments and will be discussed in Section 3 of this paper.

2.2.5. Problem Areas. Microcomputer operating systems remain a major hurdle for most applications-oriented users, such as regional planners. The various versions of MS-DOS/PC DOS, although technically well documented, are difficult to use because of a cryptic command-line user interface. However, DOS utilities, such as BACKUP and RESTORE, are essential for good management of fixed disks and for protection of data resources stored by the system. At a more general level, development of operating systems lags far behind microprocessor development. Therefore, many of the capabilities of the Intel 80286 introduced in 1984 in the IBM PC AT were not usable for applications until

1988 with the introduction of OS/2. At present, no operating system is available to fully exploit the capabilities of the Intel 80386 microprocessor used in such machines as the Compaq Deskpro 386/20 or the IBM PS/2 Model 80. If operating systems development proceeds as normal, it may be three to five years before a 80386 operating system is generally available.

2.2.5.1. Technical. The major technical problems with MS-DOS/PC DOS are the direct access memory limitation of 640 Kbytes and no facility for multitasking (running more than one program on the system at one time). Those limitations, although to some degree overcome by memory expansion protocols and DOS multitasker software--such as Microsoft's Windows, make MS-DOS obsolete in terms of the current generation of microprocessors. MS-DOS limits on direct memory access reduce the effectiveness of newer microprocessors of the Intel 80286/80386 class and force design constraints on applications software. Lack of multitasking reduces the overall productivity of microcomputers based on 80286 or 80386 microprocessors. Also, methods employed to attach peripherals, using the IBM concept of physical and virtual devices, usually mean that the system must be installed by a professional with extensive DOS experience, if any peripheral other than a simple parallel printer is in the system's configuration.

2.2.5.2. Organizational. In organizations with multiple types of microcomputers, several different operating systems may be in use. Those operating systems reflect the basic incompatibility among certain types of microcomputers. The classic case is the incompatibility between Apple and IBM microcomputers. This incompatibility leads to problems of sharing data across systems and of using one system to support another's applications when hardware fails. One of the pressing needs in planning organizations with multiple types of microcomputers is an operating system that can be used on all types of hardware. This would allow simplification of user training and cross use of hardware. Some methods, such as special disk drives and connection of machines via modem, are being used to allow PCs and Apples to share data, but applications remain restricted to the microcomputer and operating system for which they were prepared.

2.2.5.3. Operational. All of the major microcomputer systems now in use were developed in the United States, with the resultant language bias toward English. Although alternative Basic Input Output Systems (BIOS) have been developed for some major languages (Spanish, French, Chinese) and keyboard modification for most European languages is possible using the DOS configuration files (CONFIG.SYS with COUNTRY), non-English speaking users are at an initial disadvantage when using MS-DOS/PC DOS, because they must interpret the command from English to their mother tongue before using it to interact with the keyboard. The icon-based, pointer-entered command approach, such as that used by the Apple Macintosh System, may reduce the language ethnocentricity of the operating system. However, an international standard set of icons has not been developed and

implemented. Language restrictions on current operating systems mean that in planning organizations where English is not the first or second language of the professionals, more involvement of computer professionals to manage the systems and translate computer functions may be necessary.

2.2.6. Trends. Because of their design limitations, the days of MS-DOS/PC DOS are limited. Newer microcomputers, with the capacity to store more data in memory (RAM) and to do multitasking, require an operating system that allows applications programs to access that memory and fully utilize their 24- or 32-bit microprocessors (16 and 64 Mbytes). Further, the new operating system must allow the continued use of existing applications software by providing an upward migration path. To date, only Microsoft/IBM have announced a new operating system, OS/2, that directly addresses these technical problems. With the release of IBM's new user interface, Presentation Manager, a number of major applications programs are being converted (ported) to run directly under OS/2, although most MS-DOS programs will run under OS/2 with the same limitations that apply in MS-DOS (one program at a time and a maximum of 640 Kbytes of memory). Apple's Macintosh System, having been designed from the beginning to support the MC68000 family of 32-bit microprocessors, also offers a solution to the capacity and multitasking problems. Another possible operating system which may emerge as the 32-bit microcomputer standard is UNIX, which already is widely used with graphics workstations. At present, no clear standard operating system to replace MS-DOS/PC DOS can be identified. OS/2 and UNIX seem to be the major contenders, but both have serious limitations when viewed from the end-user perspective.

2.2.6.1. OS/2. OS/2 is designed to take full advantage of the Intel 80286 microprocessor, directly accessing up to 16 Mbytes of memory, and it is capable of multitasking. OS/2 is based on MS-DOS and carries forward many of the DOS problems of user friendliness. It is command-line oriented in its current version. Also, it is a much larger operating system than MS-DOS (100 Kbytes for OS/2 1.0 versus 55 Kbytes for MS-DOS 3.3). Initial review of the system indicates a much more complex operating system than MS-DOS, with no improvement in the user interface. Installation of multitasking and its use will require additional computer professional involvement in setting up the system and training the end user. It will probably take two to three years for OS/2 to generally replace MS-DOS as the operating system delivered with new microcomputers. In developing-country environments, OS/2's introduction will be further slowed. For stand-alone microcomputer applications in developing-country planning offices, only limited use of OS/2 can be expected prior to the early 1990s.

2.2.6.2. UNIX. UNIX is a systems independent operating system developed by AT&T Bell Laboratories in the 1970s. Although not widely used in stand-alone microcomputers, it allows full access to the capabilities of the new Intel 80386 class of

microprocessor and is delivered with graphics workstation hardware. UNIX's major contribution is in the area of small multi-user systems, and that will be discussed in Section 3.1. Major limitations of current versions of UNIX are the lack of an easily-understood user interface, a very complex command structure, and a lack of applications software. However, all of those problems are currently being addressed, and in certain areas, such as graphics workstations, UNIX is the preferred operating system. If current efforts to develop a better user interface are successful, UNIX could become the major 32-bit microcomputer operating system of the 1990s.

2.3. Programming Languages. Programming languages convert human-readable commands into instructions that computers can execute. This is normally a two-step process. The programmer prepares a set of commands, called "source code," using a text editor program or editor built into the language. This source code is then interpreted and executed one instruction at a time, or the source code is compiled into a machine-readable object code which is then executed. Programming (preparation of computer instructions) is an acquired skill much like reading and writing, but instead of allowing communication with other humans, programming allows a programmer to communicate with a computer. Knowledge of programming is not necessary to operate a computer or to run a specific application; however, if a planner wishes to instruct the computer to undertake special or unique operations, then knowledge of programming is needed. There are over 1,000 different programming languages now in use. These can be roughly classed into three categories -- sequential (non-structured), structured, and object-oriented. Many programming languages are designed specifically to create certain types of computer applications, e.g., Prolog or Lisp for artificial intelligence, and SIMCRIP and GPSS for process simulation and control.

2.3.1. Sequential Languages. The first general-purpose programming language to be developed provided the computer with a set of step-by-step instructions. The sequence of operation was inherent in the design of the program. This type of programming, also called "non-structured programming," typifies first and second generation programming languages, such as Fortran, COBOL and BASIC. Its strength lies in relatively simple translations of stepwise processes into computer algorithms for an application. For simple operations, a programming language such as BASIC can give the planning professional direct control of the computer allowing him to build simple models and simulations.

2.3.1.1. BASIC. BASIC is the most widely-known programming language. Most microcomputers are delivered with one dialect (version) of the over 100 BASIC dialects now in use. BASIC is simple to learn and to write, and most non-professionally prepared programs are written in BASIC. BASIC is usually converted to machine-readable form by a program interpreter, which makes the program's execution slow; however, it gives

improved error identification and program editing. A large number of programs to support regional planning activities are available in BASIC.

2.3.1.2. Fortran. Fortran is an early computer language which is still widely used in the scientific and technical community. It was designed and is normally used for the translation of mathematical formula (hence the name Fortran) and the encoding of complex equations into computer-executable forms. Fortran is a compiled language. First, the source (human readable) code is prepared using a text editor; the code is then converted to machine-executable form (compiled) using a compiler, which detects errors and converts the source code to a machine-readable object code. The object code is then executed by the computer. The advantage of compiled languages is their execution speed, which is generally several times faster than an interpreted language, such as BASIC. Normally, commercial applications are compiled, and the purchaser receives only the object code. Fortran is still widely used by scientists and engineers and remains the language of choice in many research applications. Microcomputer scientific and engineering applications are commonly programmed in Fortran.

2.3.1.3. COBOL. COBOL was developed in the 1960s by the United States government. It is the most widely-used language for programming larger mini- and mainframe computer systems for business and government applications; however, it has never been commonly-used with microcomputers. COBOL, like Fortran, is a compiled language. Its great advantage lies in its organization of data into files and forms. This makes it a very good language for such largely tabular applications as the preparation of accounting systems.

2.3.1.4. Limits of Non-Structured Languages. By their very nature, non-structured languages, such as BASIC, Fortran and COBOL, generate large amounts of computer source code. When complex applications are prepared in non-structured languages, errors in the source code are difficult to identify and remove. This increases the programming time and reduces programmer productivity, which increases the cost of the application. Also, non-structured languages are hard to use when parts of the program are prepared by different programmers. Different logic and programming styles may make it impossible to integrate various programmers' work into a single product. Although still widely used for the maintenance of existing software, development of major new, non-scientific microcomputer applications is usually not undertaken in BASIC, Fortran or COBOL.

2.3.2. Structured Languages. Structured applications languages are made up of source code modules for each function the program is to perform. The programmer prepares these modules, sometimes called "procedures," and assembles them into the required operational sequence by listing the modules. The listing and modules are then compiled to create computer-readable object codes. The advantage of structured languages lie in the

flexibility of using the modules in different relationships and combinations to build complex programs from standardized parts. Two of the most common structured languages which are used with microcomputers are Pascal and C.

2.3.2.1. Pascal. Pascal was developed in the early 1970s by Professor Niklaus Wirth of the Federal Institute of Technology, Zurich, Switzerland for use primarily in teaching students to program. There are several dialects of Pascal now in use with microcomputers (e.g., Microsoft, Borland, UCSD, etc.); however, all are similar in the commands they use and how they are programmed. Because Pascal is widely taught as the introductory programming language at many universities, it is rapidly replacing BASIC as the most common microcomputer language. Pascal is widely used for the development of complex microcomputer applications, because it produces efficient object code, it is easier to debug and correct errors than BASIC or Fortran, and it can be run on a number of different microcomputers (the source code is portable). For large applications, using Pascal to prepare the source code generally reduces programming effort by one-third when compared to BASIC, and, because of the modular structure, it is easier to use programming teams to prepare the source code.

2.3.2.2. C. C is a general-purpose programming language originally written by Denis Ritchie to use with the UNIX operating system. It is currently available in a number of dialects to prepare microcomputer applications programs. C is used widely to develop large-scale microcomputer applications. Most of the commercial wordprocessors, spreadsheets, project management software or games being sold for microcomputers today are developed (written) in C. Because of C's terse command structure and large number of operators, it is largely used by professional programmers. However, C is well suited for applications development and is often the structured applications language of choice for large software projects.

2.3.2.3. Limits of Structured Languages. Although structured programming languages offer a vast improvement over non-structured languages, the former still require special training and skills to use. They have too complex a command structure for anyone but the professional programmer or dedicated amateur to remember and use efficiently. Those limitations, which hamper the easy use of any general-purpose programming language, argue strongly for specialized languages that closely relate the field of application to the language, thereby making it simple for the non-professional programmer to instruct the computer. To date, most high-level applications languages for use by non-programmers are found in association with specialized applications programs, such as spreadsheets, data base managers, and computer-aided design and drafting (CADD) software.

2.3.3. Other Programming Languages. New versions of existing programming languages and entirely new languages are constantly under development. A new family of programming languages, called

"object-oriented," has been developed and is available for microcomputer operating systems. Recently, development of microcomputers with large memory capacity and high processor speed has led to the introduction of fourth generation programming languages for microcomputers and specialized languages for artificial intelligence research and development.

2.3.3.1 Object-Oriented Programming Languages. Object-oriented programming languages introduce the concept of hierarchy as a programming language paradigm. Object-oriented languages offer greater ability to program by establishing classes of entities and functions and by specifying relationships between entities and functions as hierarchies. Those types of relationships, which tend to typify the natural environment, have been difficult to address with structured and non-structured programming languages. The most common object-oriented, general-purpose microcomputer programming language is Smalltalk.

2.3.3.2. Fourth Generation Languages. Fourth generation languages and the programming environments they create will be discussed in more detail in the section on mainframe computers (Section 4); however, some of those programming languages are now available for microcomputers. Fourth generation languages are used for the development of very large and complex computer applications. They incorporate the concept of the operating system, structured and object-oriented general purpose applications languages, and the software support tools for the programmer into one large programming environment. Several fourth generation programming languages are available- for microcomputers, the most common being Ada, developed for the complex programming tasks of the United States Department of Defense.

2.3.3.3. Artificial Intelligence Languages. Currently, the most important field of computer applications research is artificial intelligence (AI), or the emulation of human thought processes by computers. Research approaches to AI involve both specialized hardware and software. Two of the more common programming languages especially used for AI research have been implemented on microcomputers. They are Lisp and Prolog. Both function in a similar way. The languages allow the user to define a set of rules, to show how the rules are combined and prioritized when operating on real situations (the inference engine), and to proscribe the objective set of conditions to which the rules are applied (data base). Because of the complexity of most AI problems, microcomputer applications have been trivial until recently. With the availability of the larger-capacity microcomputer, significant AI applications, such as expert systems, can now be developed and implemented on microcomputers.

2.3.4. Problem Areas. Programming and the limited availability of skills needed to program, represent the single largest deterrent to wider use of computing in developing countries. Existing programming languages require specialized training and

constant use to remain effective tools. Most planning professionals who are computer users or potential users cannot afford the time to learn programming or to practice it.

2.3.4.1. Technical. Programming languages are implemented through a set of commands. The command set is normally a subset of English (GOTO, HELP, RETURN, etc.). This immediately places non-English speakers and English-as-a-second-language speakers at a disadvantage in learning and doing programming. Various dialects of the major general-purpose languages for microcomputers contribute to the problem of developing standardized user interfaces that would simplify programming. At present, standardized command sets for BASIC and Pascal are not implemented in the most widely-used dialects (Microsoft BASIC and TurboPascal). These two examples of command set problems are indicative of the key programming challenge -- establishing a simple user interface for programming to allow wider access to the microcomputer's capabilities.

2.3.4.2. Organizational. Early microcomputer programming was typified by tasks which could be accomplished by a single programmer/analyst, who defined the requirement, established the model, and did the programming. However, the advent of more powerful hardware and operating systems opened the way to programming complex applications. No longer can a single programmer complete an application in a reasonable timeframe. Programming microcomputer applications will become similar to programming larger mini- and mainframe computers, which require teams of systems analysts and programmers. If regional planning agencies are going to undertake internal preparation of applications programs, staffing with systems analysts, programmers and trained computer managers will become an integral part of the planning agency.

2.3.4.3. Operational. Formerly, programs developed for microcomputer applications were relatively simple in design and implementation. They tended to be easy to debug and error free. As more complex applications are implemented, programs will become more prone to fail because of errors in the greater amount of computer code required to prepare the application. The application's complexity, implied by the more powerful microcomputer systems in use, also points to the involvement of computer professionals within the planning agency. Programmers will be necessary to debug, upgrade and maintain existing applications as well as develop new applications.

2.3.5. Trends. Two major trends mark programming languages -- the development of specialized languages for different types of applications and the emergence of a programming environment to support applications development with general-purpose languages.

2.3.5.1. Specialized Languages. As microcomputer applications become more specialized and varied, general-purpose languages seem to be less and less suited for divergent programming tasks. Specialized languages that reflect the operations required for a

specific type of application, i.e., simulation, text handling, and artificial intelligence, have become more important. In the future, this development may lead to specialized languages that reflect closely the processes and data operations carried out by professionals in specific fields (e.g., regional planning). If specialized, discipline-specific languages are developed, some of the problems now encountered in preparing applications software may be reduced, by making the programmer's task more easily understood to the professional planner, who will run the application and analyze the outputs.

2.3.5.2. Programming Environments. Most recent versions of general-purpose programming languages, such as Pascal, BASIC or C, have available programming environments. Those environments make programming more efficient and less time consuming by providing tools to support the programmer and libraries of source code procedures that can be incorporated into an application's programs. Examples of items in a programmer's tool box include text editors custom made for programming in a specific language, screen managers for the design of forms on the Video Display Terminal (VDT) screen, and prepared library procedures for input and output of data, graphics, text, and data base management. All of these tool box items reduce programming time and repetitive programming tasks. Future development in this area, such as natural language input, may greatly ease problems inherent in programming in non-English languages and may reduce the specialized skills and training required to provide instruction to a computer. For the professional programmer, programming environments increase productivity and the complexity of programming tasks that can be undertaken. For the planner wishing to access the capability of the microcomputer, programming environments greatly simplify learning and doing programming.

2.4. Applications Software. Introduction of the microcomputer in the late 1970s revolutionized software applications development. Prior to the microcomputer, the ratio of hardware-to-software cost was large, and most applications software was custom designed and installed on each mini- or mainframe computer. However, with the introduction of microcomputers, the hardware-to-software cost ratio reversed, and software cost easily equaled or exceeded that of the hardware. To provide lower-cost software for microcomputers, the concept of a programmer tailoring software for each individual application was replaced by the applications package -- a generic, off-the-shelf software that the user could install, tailor to a specific requirement, and operate without the involvement of a computer professional. This concept basically was realized for personal computer business applications, such as word processors, spreadsheets, simple file management systems, and communications packages. Those four generic applications comprised the first generation of microcomputer software. They have been augmented in recent years by more complex, second generation, generic applications in the areas of project management, desk-top publishing, and computer graphics.

2.4.1. First Generation Applications Software. The biggest initial impact of stand-alone microcomputers came in four areas closely related to the automation of business and professional office functions. They were word processing -- the production, storage and retrieval of correspondence and documents; spreadsheeting -- the automation of the ledger sheet and its manipulation; data base management -- the organization and presentation of interrelated data; and communication -- interfacing the personal computer to other computer systems using telecommunications.

2.4.1.1. Word Processing. Word processing applications were developed prior to the introduction of the microcomputer. However, the minicomputer-based systems were too expensive for general or personal use and were mainly confined to very large governmental or private firms in developed countries. Word processing applications software for microcomputers evolved from the text editors used to prepare all types of computer programs. The first word processor to gain widespread acceptance was WordStar, which was introduced in 1980 for the CP/M operating system. The number of microcomputer-based word processors has proliferated, and there are currently more than 100 available commercially.

2.4.1.1.1. Development of word processing software has concentrated on improving the ease of use, enhancing the number of editorial and text preparation functions, and increasing the speed of operation. Currently, word processors are available to support all major languages, including Arabic, Chinese and Hindi, which do not use conventional romanized alphabets. Also available are word processors operating in two or more languages. Word processing is the most common application of microcomputers and is usually the first application to gain widespread acceptance in either a government organization or private firm. Current systems are easy to learn, increase the ease and efficiency of administrative/substantive correspondence or document preparation, and reduce the time required for text preparation.

2.4.1.1.2. Early word processors' functions of text input, editing and formatted printing have been augmented by the addition of spelling checkers, a thesaurus, and mail-merge features that encompass all phases of the document preparation cycle. To operate efficiently, current versions of most major word processing packages require microcomputers with fixed disks. In organizations which have implemented personal computers on a wide scale, many managers and administrators prepare their letters, memoranda and reports directly on the microcomputer using word processing software. This one-system drafting of documents greatly reduces the time to circulate information within the office or to provide information to other organizations.

2.4.1.1.3. Problems. Present-generation word processing software has overcome many problems of earlier packages; however, larger packages that include many features require special

operator training to make full use of the functions. Also, word processing introduces changes in the organization's document control functions and the management of the document preparation cycle. If the changes are not addressed, internal and external communications are affected adversely.

2.4.1.1.3.1. Technical. Each word processing software package has a different user interface based on a set of keyboard commands to carry out the text-related functions. As word processing software packages have become more complex with added functions, the user interface has become equally complicated because of the proliferation of commands. This complexity requires training of clerical personnel who will use the word processor routinely. Also, the complexity limits the transfer of word processing skills from the clerical staff to the administrative and professional staff, slowing down the diffusion of word processing and other automated office concepts.

2.4.1.1.3.2. Organizational. Word processing changes the way correspondence and documents are prepared and routed in an organization. As a minimum, the traditional paper channel is augmented by a magnetic channel, where documents are transferred from machine to machine on magnetic media (disks, streaming tape, etc.). In governmental organizations, such as regional planning agencies, with strict document control involving registries, word processing can subvert the system by making physical control of the document difficult. This can cause significant administrative confusion, because more than one version of the same document may exist within the agency. Document control procedures must be modified to incorporate word processing. When word processing is introduced, procedures for handling documents in magnetic formats must be established.

2.4.1.1.3.3. Operational. One of the major problems in using word processing within regional planning organizations is that document processing can expand to fill all microcomputer capacity available at the agency. When limited computer resources are present, it may be necessary to control the number and types of documents that are word processed. In an optimum environment, clerical staff would have access to microcomputers dedicated to correspondence and document preparation; however, when this environment is not available, the word processing function should be prioritized among the rest of the microcomputer functions, and time allocated accordingly. One problem that has limited the use of microcomputers in regional planning agencies in developing countries is poor allocation of the computing resource. Many machines which could operate twenty-four hours a day are in actual use less than four hours. Better management could slot word processing and other administrative functions into certain time periods during the day, while the systems could be used for substantive planning applications at other times.

2.4.1.1.4. Trends. Two trends dominate word processor software development: increasing the simplicity of use and development of end-to-end document preparation.

2.4.1.1.4.1. **Simplicity of Use.** Early word processors required the user to learn a set of complex key-stroke commands. Those commands controlled the input and editing of text, the storing and printing of the document, and checking spelling. Newer word processing software has reduced the number of key strokes to issue the commands and has introduced use of the mouse and icons. Although not yet as easy to learn as operating a simple typewriter, recently-released word processing software can be learned without formal training by studying the tutorials and programmed instruction manuals provided as part of the software package.

2.4.1.1.4.2. **End-To-End Document Processing.** When word processing first became widely available, it was viewed as a better method of document creation. Essentially, word processing changed the method of document creation only up to the point of final clean copy. However, the development of the laser printer and screen graphics has made possible the total preparation of documents, including graphics design, layout, typesetting, and printing. These last four operations, conventionally functions of professional typesetters and printers, have been incorporated into software called desk-top publishing software. Logically, desk-top publishing functions can be built into large, word processing software packages. This end-to-end document processing is becoming a reality, when the latest generation of microcomputers with high resolution graphics is combined with the most recent versions of word processing packages, such as Word and Word Perfect, forming a document production system.

2.4.1.2. **Spreadsheets.** Spreadsheets are automated ledger sheets. They are the equivalent of word processing but handle numbers rather than words. Spreadsheets were invented and first implemented on microcomputers in the early 1980s. They have revolutionized many applications involving the analysis of numeric data. Early spreadsheets allowed the end user to input data from the keyboard into an electronic ledger sheet that could automatically add, subtract, multiply, and divide columns and rows of numbers. Current versions of spreadsheets allow the implementation of a large number of mathematical and logical operations, incorporate many data management functions such as data sort and search, can be programmed to automatically carry out many data structuring and analysis functions, and graphically display data.

2.4.1.2.1. **Spreadsheets represent an important tool kit for regional planners who are end users of microcomputers.** By using spreadsheet software and prepared programs of instructions, called "templates," the planner can analyze demographic data using cohort survivor models, study housing affordability, or graphically present locally-collected data to his superiors. Innovative analytical approaches to regional data can be developed by the planner when he has the quantitative tools of planning analysis that spreadsheets put on his desk top. With the introduction of expanded RAM and extended-memory management software, large spreadsheet-based models can be designed which

incorporate regional macro-economic input/output tables. Additionally, large socio-economic data sets of smaller planning units making up the region can be chosen to simulate regional change.

2.4.1.2.2. The key to professionals using spreadsheets to support their activities is training and support. Professionals must be taught to operate the microcomputer and the software spreadsheet package which they intend to use. They should also study any related templates or macro programs to insure that the logic used is relevant to the data and problem they are trying to analyze. After becoming familiar with using spreadsheets, many planners may eventually modify or develop their own templates to meet specific needs of their organization.

2.4.1.2.3. Problems. Current versions of most spreadsheets are complex software packages, and their many functions must be well understood to be successfully employed. Complex analytical models and data sets must be carefully programmed and checked to guarantee that no error has contaminated the result. Regional planning organizations which use spreadsheets to support quantitative analysis should assure that professional planners who are the end users of this software are well trained and aware of how the software works, so their errors do not invalidate analysis of the planning data.

2.4.1.2.3.1. Technical. Most commercially-available spreadsheets are well tested and operate as advertised. When spreadsheet software is purchased, care should be taken that the mathematical and logical functions needed for specific planning analysis are included in the package and that the graphics component (if included) will display on the organization's graphics adapter and monitor. Also, printer output graphics may require a specific printer or printer protocol, and a check should be made that the protocol is available on the system's printer. Although most current spreadsheet software can read files from other spreadsheets, it is advisable to standardize on a single spreadsheet software throughout an organization.

2.4.1.2.3.2. Organizational. While word processing supports administrative aspects of planning (document/correspondence preparation), spreadsheet software supports the core activity of the regional planner -- data analysis. Many planners in developing countries have found the transition from subjective, descriptive planning to quantitative planning analysis difficult even in a non-computer environment. The addition of the microcomputer and the required operator skills to effectively use the machine have given the planner a new set of problems. The planner must become proficient with the microcomputer as a tool and be able to use effectively the capabilities of the spreadsheet software package. Because many planners have had difficulty in adapting their workstyle to a microcomputer environment, use of small planning teams with a computer literate

member has been found effective in introducing spreadsheet analysis and in encouraging wider use of analytical models within planning agencies.

2.4.1.2.3.3. Operational. Effective use of spreadsheets depends on the availability of planning models in template form. A number of templates have been developed; however, there is no central clearing house or source for them. Also, when complex data sets and models are used, careful checking of the template is essential to guarantee that it is free of programming and logical errors. Error-checking of both data and model is a major limiting aspect of spreadsheets, since no method to identify non-logical data inputs or commands exists. In large models, this can lead to results that appear correct but are wrong.

2.4.1.2.4. Trends. Spreadsheets are second only to word processing in numbers of microcomputer applications in regional planning agencies. The major trend is in the development and use of templates for models and simulations. With the introduction of extended-memory spreadsheets and three-dimensional spreadsheets, the utility of this software for planning analysis should continue to grow. Additions and simplifications to popular spreadsheet packages should facilitate their use and programming. Integration of word processing, spreadsheets and data management functions into a single software package makes the software easier to store data, extract a subset related to a specific problem, analyze the data, and incorporate the output information into a report. Also, three-dimensional spreadsheets should be beneficial to regional planners when organizing data about planning areas within regions. With more powerful analytical and logical functions continually being built into spreadsheet software, desk-top planning analysis is rapidly becoming a reality.

2.4.1.3. Data Base Management System (DBMS). DBMSs are the third type of applications software to gain widespread use on microcomputers. DBMS software creates and manages data bases (organized collections of interrelated data). DBMS software is used to manage data and to establish relations within large sets of data which are stored in more than one computer file. At the simplest level, DBMS assists the end user to create forms for input of data to a file, to organize data for specific tasks, and to output data in user-defined reports. Where more than one file of data exist, DBMSs are used to establish relations between files and to access files to generate consolidated reports.

2.4.1.3.1. DBMSs make it easier for end users and/or programmers to carry out data management functions associated with computing. Benefits of DBMSs include: organization of data requirements into a simplified structured data model; efficient data input and storage; improved data integrity and security; and easier, more flexible access to data by the end user.

2.4.1.3.2. Regional planners use DBMS software for the same reasons that professionals who deal with large amounts of data do -- to simplify the task of data management. Planning agencies use large amounts of data. Some data are collected in the field by survey while different elements are extracted from reports or surveys conducted by other government organizations. When faced with a planning task, the agency must marshal those resources, determine the relevant data on hand, decide what must be collected, and collect the additional data. A microcomputer-based DBMS can assist in rationally organizing the planning agency's data resources for a specific task, structuring and analyzing the data, and outputting reports for planning studies and plans.

2.4.1.3.3. Problems. Because of the large number of DBMS systems available commercially, it is often difficult for end users to choose a system that both meets their needs and is simple to use. This is made more complex, because DBMSs are not end-user computing tools in the same sense as word processors. They are intermediate, high-level applications environments that make data management easier, but they still require a more complete knowledge of computing than is necessary to operate a word processor.

2.4.1.3.3.1. Technical. There are a number of different types of DBMSs available for microcomputers, and the type of DBMS software required for a specific application's data base will vary. For instance, the DBMS for regional economic and social data will require an alpha-numeric data base and DBMS, while a collection of text materials, such as abstracts, will require a text data base and an entirely different DBMS. Selection of a microcomputer DBMS to support a specific agency with a number of planning tasks should be approached with care, and planners may want to involve a computer professional in the decision.

2.4.1.3.3.2. Organizational. Although microcomputers are generally viewed as computers used by a single individual, DBMS' applications are not easily organized in such a manner. It is unlikely that the same person who inputs the data (clerical or technical) would conduct the analysis or draft the reports. This means that in stand-alone, single microcomputer environments, either the machine with the DBMS software installed must be accessible to all elements of the staff working on a specific project, or the data base must be transferred from machine to machine. Both of those options involve problems of maintaining data integrity and ease of access. No easy solution, short of local area networks (LANs), has been identified to solve this problem.

2.4.1.3.3.3. Operational. DBMS software is fairly-widely used in regional planning agencies. DBMS has made easier the organization of data necessary to conduct planning analysis; however, other than simple, single-data files, relational data base design and implementation have proven too difficult for end users to undertake without the help of computer professionals.

Professional programming support has also been found essential to use many program-implemented features of more complex, commercial DBMS packages. For most stand-alone microcomputer data bases, the large, complex DBMSs now available may be more powerful than required.

2.4.1.3.4. Trends. DBMSs continue to evolve and are headed toward standardization for all major, current types of computer systems (micro-, mini- and mainframe computers). One example of this is the widespread adoption of IBM's Standard Query Language (SQL) that allows end users standardized access to the data base. Also, commercial microcomputer DBMS companies have recognized the need to integrate word processing, spreadsheet and DBMS functions and have released products incorporating all three primary microcomputer applications. For most planning applications, the full power of DBMS software will not be realized until organizations have access to larger, multi-user computers or LANs which tie together stand-alone microcomputers. However, simple-to-use, low-end DBMSs can help individual planners deal with problems of data organization and report generation.

2.4.1.4. Communications Software. Besides special peripheral hardware, known as "modems," specialized software is required to allow computers to communicate directly over telephone lines. Communications software packages set computer and communications parameters, send and receive communications between computers, and store received communications to file.

2.4.1.4.1. Communications software ties together the two key technologies of the information age -- computers and communications. Potential applications in regional planning are apparent. They include transmission of data from the field directly to the regional planning office and vice versa, and transmission of reports and information from central planning facilities to field offices or other government agencies involved in the planning process.

2.4.1.4.2. Problems. Regional planning organizations in developing countries have made very little use of communications aspects of microcomputer applications. There are a number of reasons for this, but the main inhibitors appear to be both technical and organizational. The technical limits seem to be the generally poor quality of telephone lines and the lack of reliable telephone service. Organizationally, national posts and telegraphs have been slow to provide the necessary connect facilities to allow use of modems, and most appear to have little interest in data transmission or internal computer networks.

2.4.1.4.3. Trends. Because of growing use of data transmission by all sectors of the national economy, gradual improvement has occurred in data communications services in most developing countries. Access by government agencies to computer-compatible telephone lines and other equipment has increased as the mutual dependence of computers and communications has received wider acknowledgment. When communications are viewed as the network

connecting all levels of planning, and with planning agencies' increased sophistication in computer use, the importance of developing good telecommunications to support computer applications in regional planning will be evident.

2.4.2. Second Generation Applications. Although rapid development of microcomputer hardware in the 1980s has not been equaled by development of applications software, a number of new commercial applications packages, especially important to planners, have been introduced. They include software packages for project management, desk-top publishing and computer-aided design and drafting (CADD).

2.4.2.1. Project Management. Methods to monitor the design and implementation of complex engineering and industrial projects have been in existence since World War I, when the Gantt Chart was invented to rationalize the production of armaments. Current project management tools, such as critical path method (CP-M) and Pert, are only implemented easily with the support of a computer. In the mid-1980s, microcomputer software became available that allowed individual planners to plan and track projects for which they were responsible by using CP-M and Pert-type project management tools.

2.4.2.1.1. Project management software allows the planner to organize projects, such as the preparation of a regional plan, into a series of tasks. Project tasks are assembled by taking into account the time, personnel and resources to accomplish each task and the relationships among the tasks. Once the project is specified as a series of tasks, the project management software determines the time to conduct the project, personnel and equipment resources required, time-critical tasks and decision points, and the cost of the project. Although this type of project management has been little used in planning agencies, its potential as a tool in managing regional plans' preparation is very high.

2.4.2.1.2. Two methods of project management are now widely used: CP-M and Pert. The difference between the two systems is the degree to which the exact time must be known to conduct specific tasks. CP-M, which uses deterministic procedures to calculate time and establish critical tasks, requires high-quality information on the time and resources needed to conduct each task. Pert, which uses heuristic procedures, does not require as precise an understanding of task time and resources and may be the more useful procedure for planning environments. Both CP-M and Pert approaches have been implemented on microcomputers, and a number of commercial software packages are available.

2.4.2.1.3. Project management software also allows the planner to track or follow the progress of a project during execution. With data on actual time of completion of each task and resources used, the planner can determine if the project is on time and on

budget. Likewise, he can calculate what additional resources will be required to keep the project on time or what delays can be expected if only existing resources are available.

2.4.2.1.4. Problems. In developing countries, little use of project management methods have been made to manage preparation of regional plans in developing countries. Regional planners are not aware of either the manual or computerized methods of Gantt charting, CP-M or Pert. Any one of those methods might prove useful in controlling preparation of regional plans and determining resources necessary to prepare such plans. Using project management for tracking projects requires detailed data on the status of the project. In many cases, data are not provided or are not timely. Lack of actual data negates the value of this approach to determine project status and costs.

2.4.2.1.5. Trends. As more microcomputers become available in regional planning organizations, greater use of project management software can be expected. When used, project management tools lead to improved allocation of planning resources and better management of the planning process.

2.4.2.2. Desk-Top Publishing. Regional plans and development orders are essentially paper-based documents that require publishing (layout, typesetting, and printing) prior to distribution to government agencies and other private and public organizations. With word processing, agencies prepare the copy or text of the document on a microcomputer, but prior to desk-top publishing, they could not carry out the other steps in publishing a document. Desk-top publishing allows an organization to internalize the entire publishing process, including copy editing, lay out, typesetting, and printing.

2.4.2.2.1. Microcomputers with high-resolution video screens and laser printers, a combination of microcomputer and dry-copier technology, make possible desk-top publishing. Using a standard word processor, the text of a regional plan can be prepared, while maps and other graphics can be assembled using a CADD system. Desk-top publishing software is then run, and type styles and sizes are selected, as the text and graphics are merged on a page-by-page basis until the document is fully laid out and ready to print. The laser printer is then enabled and told the number of copies and page size to be printed. After the print run, the document need only be manually collated and bound to be ready for distribution to other persons involved in the planning process.

2.4.2.2.2. Use of desk-top publishing could overcome several major bottlenecks in the planning cycle. At present, many planning offices have draft plans that have not been distributed because of the cost of drafting maps, graphics and printing. With desk-top publishing, those operations could be made internal to the agency, and draft plans could be circulated and finalized much quicker. Ultimately, the plan that is not circulated, or

remains available only in the agency, does not support either the development process or the agency's function of providing planning information to the government and/or the public.

2.4.2.2.3. Problems. Very few desk-top publishing systems are in use in developing countries, and fewer still in planning agencies. One of the key problems will be training personnel to use the system. Desk-top publishing is still publishing, which requires a knowledge of editing, lay out and design, typography and printing. Those skills will have to be added to ones already existent in a planning agency. Also, the agency will have to provide the necessary word processing and CADD support systems to make desk-top publishing feasible. Desk-top publishing is not an entry-level application. This means that an agency must have fully operational word processing and possibly CADD systems before the benefits of those systems can expedite the publication of plans.

2.4.2.2.4. Trends. For planning agencies which have several years' experience with microcomputers and have established word processing and spreadsheet applications, desk-top publishing is probably the most likely candidate for second-generation applications among those now commercially available. Desk-top publishing will require introduction of a microcomputer with good graphics capability, such as the IBM PS/2 or Apple Macintosh, and laser printers. However, given proper staff training, an agency which has successfully employed first-generation microcomputer applications should have no problem absorbing either the hardware or software.

2.4.2.3. Computer-Aided Design and Drafting (CADD). Planning analysis relies heavily on the graphical, especially spatial, presentation of information. Planners require maps of environmental variables, land use, land ownership, and infrastructure to understand and project changes in urban areas and regions. To be a useful tool for the planner, the microcomputer must be able to assist in the storage, analysis and display of spatial data, especially the creation of maps. Until recently, microcomputers were not powerful enough to be used for mapping. However, with the introduction of the IBM PC AT class of microcomputer in 1984, hardware technology for mapping was available. Computer maps for planning became a reality with the release of CADD software packages for use on microcomputers.

2.4.2.3.1. CADD software converts the microcomputer into an automated drafting table. Using a pointing device, called a "digitizing tablet," operators can draft just as if they were working at a drafting table. This allows the input of mapping data of many different types. Data are then stored on fixed disk and viewed on a high-resolution color monitor with either an enhanced or video graphics adapter (EGA or VGA) installed in the microcomputer. Once the basic spatial data that make up a map are converted to a computer file, the data can be displayed and edited to create various thematic maps or to show raw input data

on maps. To create a paper copy of the map, it is output either to a graphics printer or a plotter, which uses drafting pens to create drafting-quality products on either paper or mylar.

2.4.2.3.2. CADD software systems can be used to design and draft any type of drawing, whether it is a map, an engineering drawing or a geologic cross section. There are currently more than 25 commercial CADD systems for microcomputers in the North American market. Those CADD systems vary in complexity, and some are specialized to create certain types of drawings. Worldwide, the most commonly-used microcomputer CADD system is AutoCAD, which is now available in most developing countries.

2.4.2.3.3. CADD systems have been used for mapping in the Town Planning Department in Jamaica. For that application, the Jamaica National Atlas and its data were loaded to an IBM PC AT using AutoCAD software. Each of the themes making up the Atlas -- geology, hydrology, soils, land use, road network -- were digitized onto a layer of a 1:250,000 base map. When those layers were displayed with the base outline of Jamaica, any of the spatial information contained in the Atlas could be reviewed and output to a plotter for preparation of a distribution map. Cost comparisons revealed that with local purchase of the entire system, the cost was approximately 20 percent of having 5,000 copies of the Atlas prepared by traditional methods.

2.4.2.3.4. Other projects using CADD have been undertaken in Barbados, where the Ministry of Housing and Lands uses a microcomputer system to maintain the inventory and infrastructure maps of 16 low-income tenencies (housing areas) on the Island. Use of the microcomputer CADD system has allowed the Ministry to study various layouts for water, sewer, power, and telephone supplies without redrafting the entire map of the tenency.

2.4.2.3.5. Problems. The more complex microcomputer CADD systems, such as those used in projects described above, require special operator training and can be used only in organizations where draftspersons can be retrained and assigned to operate the system with the planners. Simpler CADD systems having limited functions might not be powerful enough to be effective mapping tools in regional planning agencies.

2.4.2.3.5.1. Technical. The large number of CADD software packages on the market makes selection difficult, and the more widely-distributed packages are not designed specifically for mapping. In developing-country computer environments, where faster versions of the PC AT are still uncommon, existing hardware is generally poorly suited to run CADD. As a minimum, CADD should be implemented on a 10 Mhz clocked microprocessor with a math coprocessor. Also, the system will require a peripheral digitizer, color graphics display, and plotter to be complete. Most of the better CADD packages mandate special training before they can be used effectively for mapping, and training as well as software-installation support is still limited in many developing countries.

2.4.2.3.5.2. Organizational. CADD software can be an effective planning tool, but it is not an entry-level application for microcomputers. CADD requires the reorganization of planning teams to include technicians, usually draftspersons, to input and edit the data, while professionals advise and assist in determining mapping themes, presentation and content. In a planning project, it is possible that the microcomputer map data base could become the focal point of the planning team's analytical activity and a major source of materials to include in development orders and physical plans.

2.4.2.3.5.3. Operational. Because CADD is essentially drafting software, professional planners tend to turn over operation of the systems to draftspersons. Although input of data does not require professional planning skills, analysis and design of output maps do. Effective use of CADD systems in planning will require that the planner become actively involved with the system and be able to discover patterns in the spatial data the maps represent. To be successful planning tools, CADD systems must be operated by both draftspersons and professional planners. The effective use of CADD by planners will require a less-complex user interface than most systems now have.

2.4.2.3.6. Trends. CADD software is one of the most rapidly-evolving microcomputer applications. Specialized software packages, which are designed specifically for thematic and data mapping, are becoming more common. Apple computer has begun discussion of customized desk-top mapping software that would be similar to current desk-top publishing software. Desk-top mapping would allow the end-to-end production of maps on a microcomputer. However, the key problem for many map users is not generation but analysis of the spatial patterns in the map. In this area, little has been undertaken outside university research environments, and even less is available on microcomputer. Before desk-top mapping becomes a major tool for regional planners, not only production but also spatial data analysis must be improved.

2.5. Planning Applications. Review of existing custom applications software and macro templates for spreadsheets and data bases reveals a very limited number of products that have been designed, developed and tested for the support of planning, and even fewer which have been used in developing-country environments. Only four major custom applications software packages have been identified and a number of spreadsheet templates.

2.5.1. Custom Planning Applications. Four major software packages are currently available to support planning analysis in developing countries. Each of the packages has been used in developing-country planning offices, but in each case, the applications were found to require professional support for installation, training and maintenance.

2.5.1.1. BASIC Microcomputer Programs for Urban Analysis and Planning. BASIC Microcomputer Programs for Urban Analysis and Planning is a text containing nine software planning-tool programs written in BASIC. The programs include: trend analysis; cohort-survival population projection model; an economic base model; a shift-share employment projection model; an input-output projection model; a single-constrained gravity model; a double-constrained gravity model; a facility location model for a homogeneous plane; and a facility location on a network model. The programs' source code is provided, but input to the microcomputer will require someone familiar with BASIC. All of the programs have been found to run, and test data are provided; however, analysis of outputs will require that planners either have training in quantitative analysis or that training accompanies the installation of the software.

2.5.1.2. FIVFIV-SINSIN. The Population Council distributes free of charge a software package of computational methods for population projections, known as "FIVFIV-SINSIN." Release 9.0 of FIVFIV-SINSIN runs on the IBM PC or PC XT or compatibles with 256 Kbytes of RAM and either two diskette drives (5.25 inch) or a fixed disk. Programs in the package provide the planner with a full population projection system, including life tables and the ability to aggregate small-area projections into a regional projection. FIVFIV-SINSIN is one of the most widely-used, microcomputer demographic analysis packages available. The software is in operation in over fifty developing countries. It is relatively easy to install and operate, using menus to implement commands and a test data set to verify its correct installation. However, the system is intended to support the analysis of a professional demographer, and analysis of outputs may be difficult for planners without training in demography and in the use of FIVFIV-SINSIN. Full documentation of FIVFIV-SINSIN and the analytical methods it supports are available from The Population Council.

2.5.1.3. PLACE. PLACE is a location-allocation package to support site selection. It was developed by Professor M. F. Goodchild, University of Western Ontario, London, Canada to solve planning problems related to the location of central facilities, such as fire stations, schools and medical facilities. The package is written in Microsoft BASIC and will run on any IBM PC or compatible. PLACE contains four modules for locating and allocating facilities on a network, optimization and site selection, and a supporting editor. A sample data set is included to test the programs along with notes on installing and running the programs. The programs have been used in India to locate and allocate facilities in rural service centers. PLACE requires special training in location-allocation analysis to be effectively used for regional planning.

2.5.1.4. Urban Data Management Software (UDMS). UDMS is an integrated set of planning tools that allows the planner to analyze and map data using a 256 Kbyte IBM PC or compatible with a color graphics adapter (CGA) and color monitor. UDMS was

developed by the United Nations Centre for Human Settlement (UNCHS-Habitat), which distributes it free of charge. UDMS consists of six BASIC program modules which provide for data input and editing, conduct of spatial searches, regression and gravity analysis, location-allocation analysis and display, and mapping. UDMS version 5.2, which was released by UNCHS-Habitat in 1986, includes on-screen map graphics and the ability to map outputs from location and allocation analysis directly to the display. UDMS comes with both internal help screens and a User's Manual; however, neither are detailed enough for the planner to install and operate UDMS without specialized training on the system. UDMS is also prone to fail, because of poor code design, and can be frustrating to use. Nevertheless, a trained planner using UDMS has at his disposal a powerful planning tool kit in a single, integrated software package. UDMS has been installed in earlier CP/M and MS-DOS versions in over 20 planning agencies in developing countries. At present, the software is not supported with either updates or training by Habitat, and this has limited its effectiveness in developing countries.

2.5.2. Templates. Another approach to improve the regional planner's microcomputer tool kit is through the development of templates for commercial applications software, such as spreadsheets and DBMSs. A number of spreadsheet templates have been developed and are used by planners in developed countries; however, diffusion to developing-country planning offices has been slow. As with custom microcomputer software, the diffusion of templates depends upon informing developing-country planners of their existence. Because of the small number of people involved in planning worldwide, the spread of information about templates and other planning aids will probably have to be undertaken by an international organization, a non-governmental organization (NGO), or a university.

2.5.3. Problems. The general lack of software packages to support planning, either in developed or developing countries, overrides any problems generated through the use of planning applications software. Some major spatial DBMSs and analytical tools have been developed, but there is no integrated planners tool kit that would make the microcomputer a major aid in the planning process.

2.5.3.1. Technical. The quality of both planning applications software and templates reflects their origins outside the professional programming community. Without exception, the packages mentioned above require prior knowledge of microcomputers and, in most cases, a modicum of programming skills. This limits the utility of the packages to planners as end users and as materials to introduce the capabilities of the microcomputer to the planner. Also, most of the software packages are prone to end user-induced failure because of limited error trapping and fair-to-poor user documentation. If planning software were to become generally available, both the quality of the product and the documentation would have to improve.

2.5.3.2. Organizational. Experience with existing planning applications software packages, described above, indicates that to be successfully used in planning analysis, the software requires a professional programmer or planner with extensive programming experience to install, customize and maintain. Planning agencies about to use applications packages should consider the type of organizational relationship that will have to be established -- either with computer professionals or with planners having special skills who are assigned to help their colleagues in using the software.

2.5.3.3. Operational. The key operational factor in using any planning software package is training. None of the packages can be used successfully without hands-on training of the professional personnel who will conduct the analyses. Training has two elements. The first is learning to run the programs on the computer. This consists of what format the data must have; which commands to input; and how to display output. The second element is interpreting and analyzing the outputs. When complex demographic and location-allocation models are involved, the substantive analytical training is much more important and at the same time more difficult. At present, too much training emphasis has been placed on the mechanics of running the microcomputer and not enough on understanding the results produced by computation. This is especially true in developing-country planning offices, where learning to run the machine must be accomplished under pressure of transferring a foreign expert's skills in a very short time.

2.5.4. Trends. There does not seem to be a keen interest, either locally or internationally, in the development of microcomputer-based planning software. In the early and mid-1980s, UNCHS-Habitat fulfilled this role to some extent, but it has cancelled its data management program and is no longer supporting or releasing software. Also, there is no specific interest in dealing with what remains a key problem in using microcomputers in developing-country planning offices -- development of programs to meet local needs. Transfer of software from developed to developing country environments has its limits and fails to provide tools to deal with local, unique problems. More needs to be done to provide developing-country planners with microcomputer tool kits that fit their locally-defined needs and methods of analysis. Without this ability to address and use local methods, microcomputers become just another conduit to impose developed-country techniques and models on developing countries, regardless of the degree to which such methods may be appropriate.

3. Minicomputers, Super Microcomputers and LANs -- Regional Planning Projects

Although stand-alone microcomputers currently represent the major information technology resource available for regional development planning in most developing countries, it should be recognized that microcomputers may not be capable or appropriate to deal with all the computing needs of a planning agency involved with large-scale projects. Such projects may require the creation and analysis of large, relational data bases that include both spatial and non-spatial data. The data may be organized by different planners to prepare social, economic, physical, and environmental plans, and to analyze the region under development from different perspectives using different planning tools. No matter how large the capacity or fast the processing speed, stand-alone microcomputers cannot provide the levels of access needed by groups of planners working to prepare a comprehensive plan for a complex urban or rural region. When the computer is needed to support such activity, a larger, more complex computer system is required to provide the information system needed for the planning project. Currently, three computer configurations address the scope of such planning projects -- super microcomputers, local area networks (LANs), and minicomputers.

3.1. Super Microcomputers (Supermicros). The larger and faster Intel 80386 or Motorola 68000-based microcomputers described in Sections 2.1.1.3 and 2.1.2.3 can be used as the central processor for a multi-user computer system that processes instructions from more than one end user at a time. Several companies manufacture special microcomputers, called "super microcomputers" (supermicros), for use as the processing unit in such multi-user systems. Each user's workstation is connected to the supermicro by a terminal or VDU, which is similar to the keyboard and monitor of a personal computer. The main difference in hardware is the cable attachment of a number of VDUs to the central processor instead of a single keyboard and monitor. Usually, supermicros support between five and fifteen workstations.

3.1.1. Hardware. Three hardware changes make the supermicro different from the standard, stand-alone microcomputer. The supermicro will have a microprocessor which operates faster (20+ Mhz vice 3 to 12 Mhz), the RAM available will be larger (2 to 6 Mbytes vice less than 1 Mbyte), and the mass storage devices will have a greater capacity (100 Mbytes or larger vice 20 to 60 Mbytes). Normally, the terminals are attached by standard serial ports, and the system may have other microcomputer-type peripherals, such as printers, plotters and/or digitizers.

3.1.2. Operating System. Supermicros use multi-user disk operating systems. Commonly, this is a version of UNIX, but other operating systems, such as Pick and DEC's VMS, are available. Multi-user operating systems are larger and much more complex than those in single-user computer systems. Because of the complexity of multi-user operating systems and their difficult user interface, specially-trained systems personnel are required to install and maintain both the hardware/operating systems and any applications software.

3.1.3. Programming Languages. Generally, the operating system will determine what programming languages are supported. For UNIX, versions of all major programming languages discussed in Section 2.3 are available. UNIX, however, was the reason for the development of the C language, and it is common for C to be used in programming applications used with UNIX. Other operating systems, such as Pick, incorporate a programming language and data base management system directly and do not require another programming language. Custom programming of applications is more important with a supermicro than with stand-alone microcomputers, because fewer applications software are commercially available. In general, most supermicro-based applications will require some programming support to modify existing programs and may call for development of an entire custom program.

3.1.4. Applications Software. Some of the applications packages which are designed for stand-alone microcomputers can be implemented on supermicros. However, problems may arise because more than one user may try to access an application designed to operate with only a single user.

3.1.4.1. Data Base Management Systems (DBMS). It is in multi-user environments that DBMSs become very important applications tools. Supermicros seem particularly well suited to use DBMS for project-specific planning data bases in comprehensive planning projects. A DBMS package could be used to prepare a data base to store the project's survey data, data collected from other government agencies, and administrative data relative to the project. Planners on the project could be trained to use DBMS' query language to interrogate the data base and prepare subsets of data for analysis. Depending on the type of analysis (statistical, graphical or subjective), subsets of data could then be transferred to other analytical packages for analysis, or reports prepared for incorporation into planning documents. Because of the multi-user system, planning technicians and clerical staff could be trained to load the data base, edit and update it, while professional planners could concentrate on learning how to use the data base as a source of data for analysis and plan preparation.

3.1.4.2. Other Applications. Applications packages for supermicros are less common than for stand-alone microcomputers. Several financial packages for accounting and financial management have been developed, but they are largely irrelevant

to planning. Also, several geographic information systems (GIS) designed to operate on minicomputers have been converted to operate on supermicros. GISs will be discussed at length in the following section on minicomputers; however, it may be that project-specific GIS applications would be best implemented on supermicros as they become more widely available.

3.1.5. Problems. Supermicro multi-user systems have not been widely-used in developing-country environments. They represent a level of computer complexity one step above the microcomputer and, as such, will introduce problems of systems management and availability of technical staff not required for stand-alone microcomputers.

3.1.5.1. Technical. Supermicros are more complicated and difficult to maintain than standard microcomputers. The system should be equipped with an uninterruptable power supply (UPS), and the system's microprocessor housed in an air conditioned, relatively dust-free setting. Supermicro operating systems, such as UNIX, require systems' support staff who are trained in installing and maintaining the specific operating system. Local dealer support for supermicros also creates technical problems. With the exception in some regions of the DEC MicroVAX, very few of the supermicros have worldwide distribution networks and dealer support. Without local technical support, supermicros may be less applicable to developing-country environments than the more widely-distributed minicomputers, such as those built by Wang, NCR, and IBM.

3.1.5.2. Organizational. Installation and support of a supermicro multi-user system require the availability of professional computer staff either internal to the organization or available on call. Although hardware reliability is not greatly different from that of a microcomputer, the system must be more closely managed to protect the extensive data resources and the system from catastrophic failure. Trained computer professionals to manage the supermicro systems are difficult to identify in developing countries, and the expertise to repair the hardware or modify the operating system is only available on a very limited basis. The level of information technology support for the planning agency, inherent in the use of a supermicro multi-user system, implies organization of planning projects in which information systems will play a major role. At this scale, the information system to support the planning project will require the involvement of information systems specialists in the planning process.

3.1.5.3. Operational. Supermicro systems would require the division of end-user tasks among various clerical, technical and professional staff within the planning organization. End users will require training in the specific tasks which they will perform (data input, editing, analysis, or report generation), and the system, itself, will require more time than microcomputers to be brought to operational status. In organizations which have been introduced to information

technology in microcomputer form, senior management and administrative staff will tend to become impatient with the longer lead times between purchase of the system and productive use. This lead time is made greater by the need for custom programming or modifications, data input and editing, and training of all planning team members. Successful operation of multi-user systems in developing-country planning environments will depend as much on organization as computer skills.

3.1.6. Trends. Supermicro computers continue to become larger and faster. As companies that manufacture them begin to market in developing countries, supermicros' lower costs per workstation, as compared to minicomputers, should make them the multi-user technology of choice for many planning applications. Conventional differences in speed and capacity between supermicros and minicomputers will continue to be reduced, blurring the distinctions between the two types of computers. Improved availability of applications software, such as GISs, will foster interest in supermicros for development planning. The supermicro is a way for the planning team to focus on the information system which supports the plan's data resources. Such a focus, although implying organizational as well as technological change, may help to concentrate the multi-disciplinary skills of the planning team on the area being studied and may provide for better integration of social, economic, physical, and environmental aspects of the plan.

3.2. Local Area Network (LAN). LANs are combinations of hardware and software, allowing microcomputers to share mass storage devices (fixed disks), peripherals, and data by linking microcomputers together in communications networks. LANs were the obvious outgrowth of the rapid expansion of personal computers (PCs) in business and government during the 1980s. As more and more professional and administrative personnel found themselves using PCs, they quickly discovered limitations in areas of data sharing and information transmission from one person to another. LANs tie PCs together to provide the data sharing and communication that is required in organizations where data may be collected, processed, analyzed, and acted upon by different individuals who are members of a team. Planning offices obviously fall into this category of organization; however, outside developed countries, few planning offices have looked beyond the stand-alone microcomputer to the microcomputer LAN.

3.2.1. Hardware. LANs begin with the assumption that an organization already has purchased and is operating a number of stand-alone microcomputers and wants to connect them to share data and special peripherals. The LANs' hardware consists of a configuration framework, or topology, which establishes the relationship among the microcomputers and the cabling interconnecting the hardware in the LAN, the connections or taps from the microcomputers to the cabling, the special adapter boards (installed in each microcomputer) which send and receive data from the network, and a file server. The file server is a

microcomputer, usually with large, fixed-disk capacity, that manages the network communications and stores the data available to the other workstations (microcomputers) on the LAN. Other peripheral devices may be controlled by the LAN, such as printers and plotters. Although the hardware sounds complex, LANs offer relatively easy and inexpensive ways to upgrade from stand-alone microcomputing to a data-sharing environment. In developing countries, hardware for networking is supplied by most microcomputer manufacturers, including Wang, NCR and IBM.

3.2.2. Operating System. LAN hardware alone will not connect a set of microcomputers into a network. The key is the network operating system (NOS), which supervises communications between microcomputers, manages shared data resources on the file server, and allows access to the network. At present, most NOSs operate in conjunction with MS-DOS/PC DOS 3.1 or higher. The expanded NOS/DOS environment provides for access methods, that permit the end user to sign on to the network, and protocols, that interface applications programs and allow entry to the network's shared data resources. Although LAN hardware has been the focus of discussion in articles, it is the NOS and related access methods and protocols that are more important, because they determine the efficiency of the LAN overall. There are a number of NOS products now available in the international market, including Microsoft's MS-NET, IBM's PC Network Program (PCNP), and Novell's NetWare.

3.2.3. Programming Languages. Most major applications programming languages can be used to program for the LAN environment. Care must be taken to guarantee that the LAN protocols are included in the program, if it is to access data from the file server or if it is to be run by end users over the network.

3.2.4. Applications Software. Since the release of MS-DOS/PC DOS 3.1 in 1985, most major microcomputer commercial applications programs have been modified to operate on a LAN. Sometimes special versions must be purchased; however, most current versions of commercial word processors, spreadsheets and DBMSs will operate from a file server. Sometimes special versions must be installed, so careful attention to the installation instructions accompanying the applications is essential. As with supermicro multi-user systems, DBMSs play a major applications role in LAN environments. Tasks can be distributed among end users and data shared. However, some sophisticated data basing applications, such as GIS, have been found to work better as a multi-user rather than a network application.

3.2.5. Problems. There has been even less experience with LAN in developing countries than with multi-user systems. Problems that will be encountered in LAN use should parallel those with supermicros: the need for local technical expertise to install

and maintain the system; requirements for internal organizational and managerial changes to fully utilize the data resource represented by such a system; and technical problems of operating in developing countries.

3.2.5.1. Technical. Two problems with LANs have been identified in their general use which would be particularly critical in developing countries. LANs require extremely stable power environments. Power fluxes can cause the loss of data being transferred between a workstation and the file server. Also, LANs require more systems support and intervention than the stand-alone microcomputer. The additional complexity of the NOS, and its interface to the DOS, causes LANs to fail more often than stand-alone microcomputers. Therefore, many larger LANs require a network supervisor, who is responsible for maintaining the LAN and assisting other end users in working with the network.

3.2.5.2. Organizational. LANs represent a good way to integrate the distributed computing resources in stand-alone microcomputers. Using a LAN, planning professionals and staffs can share data and programs while maintaining control of special data resources only relevant to a specific planner's analysis or expertise. Because so few LANs are currently being used in planning organizations, it is difficult to assess the actual organizational problems that may arise; however, data security and access would be likely candidates. This may lead to senior planners becoming involved in such information systems' problems as, who has the right to access certain data, and who controls what data resources.

3.2.5.3. Operational. Although LANs use microcomputers as workstations, they do not offer the same operational performance as stand-alone microcomputers. Waiting for the LAN system to respond has frustrated some end users who, therefore, do not like working in a LAN environment. However, recent releases of LAN software and new file server hardware, especially the very fast Intel 80386-type microcomputers, have reduced such complaints by end users. End users also feel that LANs diminish their personal control of the computer and their data. This cannot be easily remedied and may be the price paid for access to general data resources offered by file servers.

3.2.6. Trends. With many developing-country planning offices already using microcomputers, and a number having several available, it is rational to assume that LANs will be a major growth path for computing in developing countries. Problems do exist; it is a large jump from a collection of stand-alone microcomputers to a LAN. Part of the jump is technical. Introduction of both computer and communications technologies into the information systems' matrix makes the technology-transfer problem more complex. Part is organizational. LANs are complex systems that require management on an institutional scale. This means more administrative support, management time, and financial resources will have to be committed to information technology than was the case with stand-alone microcomputers.

3.2.7. One positive aspect of being behind the leading edge of the technological curve will help developing countries in using LANs. The last five years of LAN product development has provided the developing-country planning office with a product that is cheaper, easier to install, and easier to use than the early LANs. Other problems will be worse, including the ability of local dealers to support the LAN and the availability of spare parts in case of hardware failures.

3.3. Minicomputers. Minicomputers were first introduced in the early 1970s as low-cost alternatives to mainframe computers. Many of their initial applications would be thought of today as minicomputer tasks. Just as microcomputers have grown in capacity, so have minicomputers. Minicomputers are now multi-user systems which vary greatly among themselves in speed and memory. A small minicomputer could be used to implement a single, planning project information system, while the large systems could support several planning projects' data bases simultaneously,

3.3.4.2.3. GIS technology is supplied by a limited number of small firms and is not well supported in most developing countries. Although GIS represents a powerful tool, until the local computer community can support this type of sophisticated application, it will be difficult for developing-country planning agencies to use GIS. Planning agencies which have a critical need should also be aware that GIS is a data-intensive approach to planning, and if local planning data are of poor quality or nonexistent, GIS does not represent a good use of an agency's computer, human, or financial resources. Prior to installing a complex GIS application, a planning agency should develop an overall plan for an information system, computer applications, and data support, even possibly gaining management and end-user experience with simpler applications.

3.3.4.3. Remote Sensing Image Analysis. Since 1972, satellite imaging of most of the earth's surface has occurred on a routine basis. Data obtained may be of special importance in planning for large regions and, more recently, with the introduction of high-resolution imaging from satellites, for urban areas as well. The high-speed processing ability of a minicomputer makes possible digital image analysis of satellite data in planning agencies. Although little-used at present, under conditions of rapid environmental or development-induced change, remote sensing could provide early indicators of events requiring immediate response.

3.3.4.3.1. Satellite image analysis has been difficult for most planning agencies to integrate into the planning process. There are a number of reasons for this, including the need for special technical skills to analyze the digital data, no easy way to relate the satellite data to conventional planning data, and the inability of the agency to control the analysis. Minicomputer-based technology and software have overcome many of the difficulties. When the completed analysis of a satellite image is loaded to a GIS as a new thematic map or layer and analyzed by a planner as part of the overall spatial data for a region, both the method of introducing remotely-sensed data and the method for continuous monitoring are added to the planner's tool kit.

3.3.4.3.2. A number of image analysis packages are available for minicomputers and have been used in developing countries. However, few have been closely associated with development planning. Usually, the systems have been in remote sensing agencies, whose final products were studies that seemed to have little impact on governmental planning or decision making. New technologies which combine image analysis and GIS functions of minicomputers may enhance the utility of remote sensing data. Developing-country planners should make certain that support to acquire satellite data on a continuing basis is available, and that operation of a system as complex as an integrated imagery analysis and GIS minicomputer system can be sustained from local resources.

3.3.5. Problems. Use of minicomputers in development planning is made difficult by the need to develop internal management skills to administer the computer, create the data bases, and provide end-user training and support. Minicomputers may reduce some of the local, hardware-support problems identified with microcomputers, but the lack of applications software will probably require the agency to have available internal or consultant personnel who can program applications for the system.

3.3.5.1. Technical (Hardware). Minicomputer hardware, especially central processor units and disk drive units, require better environmental control than microcomputers. The larger the minicomputer, the better controlled the environment must be. Usually, a minicomputer needs a dedicated direct power line, a UPS, air conditioning, and a room relatively free from dust and dirt. If the local dealer is providing good support and the environment is properly maintained, the minicomputer should operate reasonably problem free. All hardware maintenance will have to be conducted by the local dealer, and maintenance contracts are recommended on such items as the central processor, disk drives, and high-speed printers.

3.3.5.2. Technical (Software). Very few off-the-shelf applications packages exist for minicomputers, and most applications software is custom prepared. Problems then arise with hiring qualified systems analysts and programmers. Even commercial software packages may have to be modified to operate on locally-available and supported hardware. Also, packaged

commercial software is often not locally supported and will require the use of foreign experts to install and support the software as well as train the personnel to use the package. Unless the software package is extremely well suited for specific planning needs, or the foreign distributor has a local vendor, it may be better to develop the applications software locally. One sound rule of computer use in developing countries is to employ software that is supported by local consultants or vendors.

3.3.5.3. Organizational. As with all information technology described in this section, minicomputers will require the development of expertise within the planning organization to manage computer resources -- hardware, software and technical personnel. If those skills are not promoted at the management level within an organization, information technology will be difficult to integrate into the day-to-day planning operations, and computer use will remain limited. Management's awareness of the role the information system is to play, and how it is to provide support to other agency planning activities, is critical if minicomputers are going to be successfully used in development planning. Management's evaluation and oversight of applications requirements provide the impetus for the information system staff to meet the needs of end users.

3.3.5.4. Operational. End users of minicomputers do not have the positive control over the computer that is experienced with microcomputers. Depending upon exactly what the end user does with the application, he will require special training and support. However, all users should have some general orientation to the system and the application, so that they can understand their specific function in terms of the overall purpose of the application. Because minicomputers tend to be operated and programmed by experts, possibly in a different division of the organization, end users may be alienated from the application and not perform their functions well. It is often overlooked by technocrats who design and develop information systems that the human end user has been responsible for more failed computer systems than any technical aspect of computer hardware and software.

3.3.5.5. Special problems have arisen with the use of GIS technology in planning agencies. There is considerable lag time involved between the purchase of GIS hardware/software and the actual ability of the GIS to produce useful analysis and reports. This is caused by the lengthy time needed to convert paper-based data (maps, tables, etc.) to electronically-usable data, and the need to train all levels of the agency to use the new tool. It is not uncommon for two years to pass before enough data are available on the system and the experience level of personnel is such that useful planning can be accomplished. This lag time is difficult to overcome with existing technology and should be clearly understood as part of the installation cycle. Many senior government officials, who have expected to see immediate improvement in planning and more timely planning, have been disappointed in the short term by GIS.

3.3.6. Trends. Minicomputer systems can be expected to continue to improve in both capacity and operational speed. Also, costs of hardware should continue to decrease. It is problematic whether more applications packages of interest to planning agencies will be developed; however, GIS software should continue to improve, and devices which allow quicker conversion from paper to magnetic products are under development. Remote sensing data should also become easier to integrate into GIS, with the development of interactive workstations that combine satellite data with digital maps and geographic data bases.

3.3.6.1. Although not yet in use for planning, the artificial intelligence (AI) concepts of expert systems offer many potential uses. Expert systems could be developed to support planning decisions about land capability and land use, as well as development control. Further, AI approaches have been proposed to assist in analysis of data stored in a GIS' spatial data base. Although probably five to ten years from operational use, expert systems and AI concepts will probably play a large part in codifying planning decisions and removing subjectivity and bias.

3.3.6.2. Availability of high-speed minicomputers and smart microcomputer-based graphics workstations should allow planners in the near future to do classic map analysis in real time on graphics terminals. A session of graphics analysis might include using several thematic map overlays to define a region, compare its current land covers, show most favorable land uses based on soils, vegetation, hydrology and slope, locate service centers for optimum agricultural uses given existing and proposed transport networks, and project population changes based on this land use configuration. Such analysis, which could take several months with existing technology, could easily be accomplished in a few hours with a GIS and a graphics workst

3.3.4.2.3. GIS technology is supplied by a limited number of small firms and is not well supported in most developing countries. Although GIS represents a powerful tool, until the local computer community can support this type of sophisticated application, it will be difficult for developing-country planning agencies to use GIS. Planning agencies which have a critical need should also be aware that GIS is a data-intensive approach to planning, and if local planning data are of poor quality or nonexistent, GIS does not represent a good use of an agency's computer, human, or financial resources. Prior to installing a complex GIS application, a planning agency should develop an overall plan for an information system, computer applications, and data support, even possibly gaining management and end-user experience with simpler applications.

3.3.4.3. Remote Sensing Image Analysis. Since 1972, satellite imaging of most of the earth's surface has occurred on a routine basis. Data obtained may be of special importance in planning for large regions and, more recently, with the introduction of high-resolution imaging from satellites, for urban areas as well. The high-speed processing ability of a minicomputer makes

possible digital image analysis of satellite data in planning agencies. Although little-used at present, under conditions of rapid environmental or development-induced change, remote sensing could provide early indicators of events requiring immediate response.

3.3.4.3.1. Satellite image analysis has been difficult for most planning agencies to integrate into the planning process. There are a number of reasons for this, including the need for special technical skills to analyze the digital data, no easy way to relate the satellite data to conventional planning data, and the inability of the agency to control the analysis. Minicomputer-based technology and software have overcome many of the difficulties. When the completed analysis of a satellite image is loaded to a GIS as a new thematic map or layer and analyzed by a planner as part of the overall spatial data for a region, both the method of introducing remotely-sensed data and the method for continuous monitoring are added to the planner's tool kit.

3.3.4.3.2. A number of image analysis packages are available for minicomputers and have been used in developing countries. However, few have been closely associated with development planning. Usually, the systems have been in remote sensing agencies, whose final products were studies that seemed to have little impact on governmental planning or decision making. New technologies which combine image analysis and GIS functions of minicomputers may enhance the utility of remote sensing data. Developing-country planners should make certain that support to acquire satellite data on a continuing basis is available, and that operation of a system as complex as an integrated imagery analysis and GIS minicomputer system can be sustained from local resources.

3.3.5. Problems. Use of minicomputers in development planning is made difficult by the need to develop internal management skills to administer the computer, create the data bases, and provide end-user training and support. Minicomputers may reduce some of the local, hardware-support problems identified with microcomputers, but the lack of applications software will probably require the agency to have available internal or consultant personnel who can program applications for the system.

3.3.5.1. Technical (Hardware). Minicomputer hardware, especially central processor units and disk drive units, require better environmental control than microcomputers. The larger the minicomputer, the better controlled the environment must be. Usually, a minicomputer needs a dedicated direct power line, a UPS, air conditioning, and a room relatively free from dust and dirt. If the local dealer is providing good support and the environment is properly maintained, the minicomputer should operate reasonably problem free. All hardware maintenance will have to be conducted by the local dealer, and maintenance contracts are recommended on such items as the central processor, disk drives, and high-speed printers.

3.3.5.2. Technical (Software). Very few off-the-shelf applications packages exist for minicomputers, and most applications software is custom prepared. Problems then arise with hiring qualified systems analysts and programmers. Even commercial software packages may have to be modified to operate on locally-available and supported hardware. Also, packaged

commercial software is often not locally supported and will require the use of foreign experts to install and support the software as well as train the personnel to use the package. Unless the software package is extremely well suited for specific planning needs, or the foreign distributor has a local vendor, it may be better to develop the applications software locally. One sound rule of computer use in developing countries is to employ software that is supported by local consultants or vendors.

3.3.5.3. Organizational. As with all information technology described in this section, minicomputers will require the development of expertise within the planning organization to manage computer resources -- hardware, software and technical personnel. If those skills are not promoted at the management level within an organization, information technology will be difficult to integrate into the day-to-day planning operations, and computer use will remain limited. Management's awareness of the role the information system is to play, and how it is to provide support to other agency planning activities, is critical if minicomputers are going to be successfully used in development planning. Management's evaluation and oversight of applications requirements provide the impetus for the information system staff to meet the needs of end users.

3.3.5.4. Operational. End users of minicomputers do not have the positive control over the computer that is experienced with microcomputers. Depending upon exactly what the end user does with the application, he will require special training and support. However, all users should have some general orientation to the system and the application, so that they can understand their specific function in terms of the overall purpose of the application. Because minicomputers tend to be operated and programmed by experts, possibly in a different division of the organization, end users may be alienated from the application and not perform their functions well. It is often overlooked by technocrats who design and develop information systems that the human end user has been responsible for more failed computer systems than any technical aspect of computer hardware and software.

3.3.5.5. Special problems have arisen with the use of GIS technology in planning agencies. There is considerable lag time involved between the purchase of GIS hardware/software and the actual ability of the GIS to produce useful analysis and reports. This is caused by the lengthy time needed to convert paper-based data (maps, tables, etc.) to electronically-usable data, and the need to train all levels of the agency to use the new tool. It is not uncommon for two years to pass before enough data are available on the system and the experience level of personnel is such that useful planning can be accomplished. This lag time is difficult to overcome with existing technology and should be clearly understood as part of the installation cycle. Many senior government officials, who have expected to see immediate improvement in planning and more timely planning, have been disappointed in the short term by GIS.

3.3.6. Trends. Minicomputer systems can be expected to continue to improve in both capacity and operational speed. Also, costs of hardware should continue to decrease. It is problematic whether more applications packages of interest to planning agencies will be developed; however, GIS software should continue to improve, and devices which allow quicker conversion from paper to magnetic products are under development. Remote sensing data should also become easier to integrate into GIS, with the development of interactive workstations that combine satellite data with digital maps and geographic data bases.

3.3.6.1. Although not yet in use for planning, the artificial intelligence (AI) concepts of expert systems offer many potential uses. Expert systems could be developed to support planning decisions about land capability and land use, as well as development control. Further, AI approaches have been proposed to assist in analysis of data stored in a GIS' spatial data base. Although probably five to ten years from operational use, expert systems and AI concepts will probably play a large part in codifying planning decisions and removing subjectivity and bias.

3.3.6.2. Availability of high-speed minicomputers and smart microcomputer-based graphics workstations should allow planners in the near future to do classic map analysis in real time on graphics terminals. A session of graphics analysis might include using several thematic map overlays to define a region, compare its current land covers, show most favorable land uses based on soils, vegetation, hydrology and slope, locate service centers for optimum agricultural uses given existing and proposed transport networks, and project population changes based on this land use configuration. Such analysis, which could take several months with existing technology, could easily be accomplished in a few hours with a GIS and a graphics workstation.

4. Mainframe Computers -- Regional Planning Organizations

Mainframe computers are the largest multi-user, multitasked computer systems. General-purpose mainframe computers are a shared information resource used by entire organizations. In a governmental context, a single mainframe installation might provide information systems for a ministry, or possibly the entire government. As we know them today, mainframe computers began in the 1960s with the introduction of the IBM 360 series computers. Those computers had a hierarchy of hardware, an operating system, applications language, special tools, and applications. Many line commands used today with all types of computers were first part of the Job Control Language (JCL) for the System 360 or the follow-on System 370 computers. Current versions of mainframe computers have much greater capacities and capabilities than their 1960s forerunners, and they share many applications with larger minicomputers. Mainframes are identified by their capabilities to support hundreds of end users and run several different applications at what appears to be the same time. In many cases, current mainframe computers have several central processors linked together and controlled by the operating system. In most developing countries, mainframe computers are the responsibility of a central computer agency or department, and planning organizations may have access through VDUs linked by telecommunications. Rarely would such a large computer resource be dedicated solely to planning activities or a single planning agency.

4.1. Hardware. Worldwide, approximately 12 multinational firms and government parastatal organizations build and supply general-purpose mainframe computers. Those machines are differentiated from minicomputers by the number of users and applications they support. Mainframe computers normally have throughput rates of greater than 250 MIPS, memory of several Mbytes, and support several hundred Gigabytes of mass storage. Also, mainframe computers may have more than one central processor. To be able to support the high rates of throughput, special output devices (such as laser printers that operate at rates of 10,000 CPSs) have been developed. Each mainframe hardware installation is custom configured to meet the needs of the institution that uses the computer system. Most mainframe computers support large numbers of VDUs, both at the installation and off site in other offices and locations. This requires special hardware to support the complex network of VDUs and, in large installations, special personnel to deal solely with the interface between the communications system and the computer. Although the cost of mainframe computers has dropped in recent years, a major installation's hardware suite will be several million dollars.

4.2. Systems Network Concepts. Because of the complexity of the computer system implied by mainframe, mini- and microcomputers operating within the same organization, some system to link or network them is essential. Most organizations that require the computer capacity of a mainframe will require a network to link computers of various sizes to fulfill specific computing tasks within the organization. Individual end users may have microcomputer workstations that provide capacity for personal computing applications, such as word processing and spreadsheets. Those personal computers may be linked by LAN to other personal computers in the same department to share the resources of a DBMS system. The file server of the departmental LAN may act as a gateway to a divisional minicomputer supporting a DBMS system and specialized applications for use in the division. The divisional minicomputers may be linked to the mainframe to provide for computing applications that support the management and administration of all parts of the organization. This hierarchy of information technology, which parallels the structure of both commercial and governmental organizations, requires standardization of data and communications. Standardization is one of the main problems facing computer systems integration in the next few years. IBM has proposed one set of standards called Systems Network Architecture (SNA); however, SNA has not been widely accepted outside of IBM. The International Standards Organization (ISO) has also presented a draft protocol for networking computers (ISO X-25), but again, ISO X-25 has not been widely adapted or employed. However, the pressing need for such standards continues to grow, as computer and communications technology converge and complex computer systems, involving many types of computers, become more desired and common.

4.3. Operating Systems (OSs). Mainframe computer OSs are very complicated, sometimes requiring many Mbytes of memory just to load. The OSs incorporate several layers beyond control of the basic input-output and utility functions found in a microcomputer's OS, such as MS-DOS. Included are security and access, telecommunications, multitasking, multiprocessor control, multi-user use, job prioritization, and output (print) queueing. A large mainframe computer's memory may be as much as 70 percent devoted to what can be considered OS functions, prior to loading any applications programs. To install and maintain a complex mainframe, OS requires specialized systems programmers, who work exclusively on operating systems to upgrade and maintain them. In a developing country, it is a shortage of systems programmers that contributes to making support of a mainframe computer very difficult.

4.4. Programming Languages. Most of the applications' programming languages discussed previously are available with mainframe OSs. Other new languages and software engineering tools are available and under development to improve the efficiency and quality of applications programs used with mainframe computers. Those include fourth generation languages, which integrate the OS, the programming language, input/output screen design, and DBMS functions to speed the programming

process. Software development currently is the major limitation on many mainframe systems. End users cannot use the systems without special applications programs to access the data, to conduct the analysis, and to prepare required reports. It is applications programming that creates the bottlenecks and frustrations in using information systems dependent on mainframe computers.

4.5. Applications. Access to mainframe computing for most developing-country planning agencies is through the national computer center or a major ministry. Currently, the applications are limited to large, input-output, transportation and urban models supplied by donor agencies and installed by foreign experts. The models normally are run on a limited basis, and the results are poorly integrated into the agencies' on-going planning activities. For use in studies, the planning agency may request that special census reports be generated. Demographic data are treated by planners as if extracted from paper-based census reports. Currently, most developing-country planning agencies have had little experience in the direct employment of mainframe computer technology. Administrative tasks, such as development control, may be tracked or reported using a mainframe computer, and clerks may submit payroll and other accounting data to a central facility for processing.

4.5.1. Most of the types of applications -- GIS, remote sensing data analysis, expert systems -- that run on micro- and minicomputers can be run on mainframe computers. The chief difference is that for mainframe computers, even large-scale GIS and remote sensing applications can be housed within the same machine, while for minicomputers, each application might require a separate computer.

4.5.2. In larger, national and regional planning agencies, mainframe computers can be effectively deployed for a number of applications. Among those applications are a national GIS, to monitor physical aspects of national development, to standardize data for preparation of regional and urban plans, and to store data bases used to support all planning efforts within the country. Such a large, complex national GIS would take many years to develop and a full-time computer staff to maintain. Any planning agency attempting to develop such a system would need to establish a Management Information System (MIS) Division within the organization. The MIS would be responsible for the management of the organization's information resource, including computers, data collection, and data management. The MIS director would be the senior manager responsible to the senior staff of the planning agency for the successful development and operation of all information systems and information technology within the agency.

4.5.3. Although planning agencies are usually viewed as non-administrative in nature, solely providing information to the political/bureaucratic arms of the government and to the public, many planning agencies have responsibility to monitor and control

development under the national planning law. When such responsibilities are part of a planning agency's brief, computers can be used to administer the planning law and to assist in the control of development. The type of computer used for a development-control information system will depend on the size of the territory to be administered, the degree of governmental control over the use of land and other resources, rates of physical development, and the administrative system used for development control. In developing countries with centralized physical planning, an extensive development-control information system could require the computing capacity of a mainframe computer, especially if the system was one of several administrative and planning applications operating on the computer. Although often overlooked by planners, large development control systems could play a substantive role in planning by providing a source of data on such critical regional development indicators as land use change, investment, job creation, and migration. Other planning administrative functions may require large-scale, general-purpose mainframe computers, because of the size of the data base or the need to support many end users who are spread over a large area.

4.5.4. Mainframe computers also offer the potential to build national planning information systems that support multi-sectoral planning activities normally conducted in several different government ministries. Inter-ministerial cooperation has never been a strong point of bureaucratic systems used by most governments; however, an inter-agency information system, controlled by an outside organization, may be able to bridge the communications gap and make possible the development of inter-agency plans. The concept of a national planning information system is relatively simple. Each ministry inputs that portion of the substantive planning data relative to its field of competence, i.e., Ministry of Health -- health statistics, Ministry of Labor -- labor statistics, Central Bureau of Statistics -- census and sample surveys. Each user agency, such as the national planning agency, can access the data base to extract data for planning and analysis. Regretfully, although simple to describe, no complex inter-agency computer system for national planning has been fully implemented. Those that have been attempted have been found difficult to operate successfully, because sectoral agencies do not want to share data with other agencies and planning organizations, and the complex data base is hard to load and edit.

4.6. Problems. Local support of mainframe hardware and OS software is one of the critical problems for mainframe computer facilities in developing countries. Currently, many parts of the developing world lack this underlying computer infrastructure. Hardware engineers and OS specialists are not available for hire at government civil service wages, and local branches of major computer firms do not have enough qualified, customer-service engineers or available spare parts to maintain the installed

computers. Frustrating long waits for spares and staffing problems make the installation of mainframe computers a very unappealing information-technology option in most developing countries.

4.6.1. Technical. Mainframe hardware usually requires on-site vendor support. This will limit the choice of hardware to firms that have local staff to install and maintain the computer system and peripheral devices. Also, because of the complexity of the hardware and software and the number of alternative system configurations, more attention must be given to the correct choice of various system's components. Due to problems with equipment and software incompatibility when supplied by different computer vendors, personnel in charge of procuring the computer system must make sure that the proposed configuration will, in fact, host the desired applications. Procurement decisions are made more difficult in developing countries because of the limited types of hardware and applications software that can be supported locally. Unless the local computing environment is capable of providing backup for a mainframe system, or an agency has available a number of qualified hardware engineers, systems analysts and programmers, operation of a mainframe computer installation is fraught with difficulties and may fail.

4.6.2. Organizational. Introduction of a mainframe computer facility and its information systems applications can cause major organizational changes. Many job descriptions will require modification to include end-user computer skills, large portions of the staff may require specialized training, and administrative procedures may be modified. Unless carefully prepared for and carried out, all of those changes can cause disruption in the ability of the organization to carry out its primary function -- planning, and its administrative functions -- development control.

4.6.2.1. To implement and operate a mainframe computer will require the formation and staffing of an MIS. The MIS staff will manage/operate the computer resource on a day-to-day basis, act as the agency's internal expert in dealing with vendors, assist users in defining applications, develop, debug and modify applications software, and train end users to work with their application. In the face of these technologically-induced changes, with both new technology and new personnel being brought into the organization, senior administrators and planners must have a clear understanding of what they want the information technology to accomplish. They must also be aware that the technology itself and the personnel that service and operate it will change their organization in very fundamental ways.

4.6.2.2. One of the complaints common to end users of mainframe computers is that they cannot get the system to produce information products that they need. To a degree, this problem is caused by the increased distance between a user and the computer system. All user requests for services flow through the MIS. The MIS then prioritizes the requests and acts on them as

programming resources are available. This means that any given user's request may take weeks or months to be converted into an application that the user can actually run himself. Such lags between user information needs and what the information systems can produce have made mainframe installations and their accompanying MIS bureaucracies generally unpopular with end users.

4.6.3. Operational. Serious problems hamper the use of mainframe-based planning information systems and GIS. Those problems are the long delay between initial introduction of the hardware and software and the production of information products useful to the organization.

4.6.3.1. Full implementation of information systems, especially GIS, can take from three to five years after delivery of the hardware and software. Mainframe computer installations require large-scale data conversion, detailed data editing, and extensive operational testing before information products can be produced and used with confidence in planning activities. Long delays, between the outlay of large amounts of money to purchase a system and the ability to use the system effectively within an organization, have caused many users to question the viability of mainframe computer-based information systems in environments where money is limited and information needs are immediate. To date, no totally successful strategy has emerged to reduce the time to install, test and integrate a large computer system and its applications into an organization.

4.6.3.2. Large mainframe-based information systems contain data that may be sensitive to the individual citizen (confidential surveys) and to the government. Those data must be protected from inadvertent disclosure, or intentional unauthorized searches and tampering. To accomplish this, security procedures must not only be built into DBMSs, but users' access must be limited to that portion of the system which directly concerns their work. Security and access control are a major on-going operational problem with large, mainframe-based information systems, and will remain so for some time to come.

4.6.3.3. Although mainframe computers and information systems to date have played a very limited role in development planning, the continued diffusion of computer and telecommunications technology will probably give planners in developing countries greater accessibility to mainframes in the next decade. With this access will come the kinds of problems already identified with using large information systems in the developed world, plus new ones created by unique conditions found in the developing world.

4.7. Trends. Trends affecting mainframe computing can be divided into two major types: cost reductions, which are reversing the ratio of hardware to software costs; and attempts to develop software tools, which can speed the preparation of programs and make it possible for end users to communicate in natural languages with the systems.

4.7.1. Until the mid-1980s, the cost of purchasing and installing computer hardware usually exceeded, by a multiple of ten, the cost of personnel to operate the system and to develop the applications. However, those figures are currently reversed. In most cases, costs of hardware, even mainframe computers, have fallen to the level that software development and personnel costs now equal or exceed charges for hardware. Hardware costs can be expected to continue to drop as new wafer production technologies and automation reduce the unit cost of computer components. However, unless major breakthroughs are made in programming computers and data conversion, overall costs of an information system may remain relatively stable for the next five years.

4.7.2. One of the key areas of research in computer science is in software development. The focus of this research is to find ways to improve the efficiency of programming or develop new methods of human/machine interaction which reduce programming. For a number of years, computer scientists have tried to develop an automatic programming system (APS) which would allow the end user to define his requirements directly to the computer, and the computer, itself, would prepare the applications program. To date, no successful APSs have been developed; however, several recently-released approaches to programming may greatly enhance the efficiency and quality of applications programs. One simple change to programming and DBMS languages has been the introduction of commands that allow the user to communicate with the computer in a more human-like language, usually English. Full implementation of human language interaction with computers remains a subject for research in the AI community and will probably not be seen in the applications environment for a decade. At present, commercially-available tools to speed program development include database query systems, such as SQL and English, fourth generation programming languages, and program generators. The most promising recent breakthrough is the development of Computer-Aided Software Engineering (CASE) tools. CASE extends the programmer's tool kit and program library concepts by introducing the computer itself as a programming assistant. CASE supports the programmer in a step-by-step approach to software development that automates many of the time-consuming repetitive and simple programming tasks. The trend toward automatic programming will continue, its need insured by the large and complex information systems and computer applications that can be used with high-capacity computers that define the progress of information technology.

5. Systems Implementation

As the preceding sections of this report have pointed out, introduction of information systems and information technology can cause major changes within a planning agency. Changes can enhance the organization's ability to carry out its planning function, or weaken it. The impact of information systems will be largely determined by how the technology is brought into the organization to create the information systems. Regretfully, there are no rules that guarantee the successful transition from manual data handling methods and administrative systems to information systems. However, a few guidelines derived from experience have been found to help in the implementation process. Most successful systems' implementations are a unique combination of local planning methods, the administrative system, and information technology that can be sustained in a given country.

5.1. Guidelines. The following five guidelines have been found to be helpful in successfully implementing information systems in developing countries. They are based both on the author's personal experiences with and evaluations of computer applications in development projects.

5.1.1. Incremental Introduction. Planning for the system should take into account that the financial, management and personnel resources of most developing-country planning agencies will not allow absorption of all computer technology usable at one time. Implementation should be undertaken on an incremental basis. The best approach is to draft a data management or computerization plan that covers a two-to-four year period. In the plan, overall objectives of using information systems are established and a step-by-step implementation plan is prepared that focuses on specific applications, personnel requirements, management decisions, administrative changes, and costs. Senior staff thus is fully aware of the impact of the technology on the organization and its costs, and organizational commitment is achieved prior to the beginning of the computerization process.

5.1.2. Least-Complex Configuration. In any information system's implementation, there are a number of technology choices. For developing-country applications, it has been found that the choice of the least-complex hardware/software configuration is more likely to result in the most successful system. The corollary to this guideline is the selection of locally-available and supported hardware and software. Computer systems cannot be kept operational unless there are local sources of maintenance and upgrade. Although it may be tempting to use the most advanced technology, unless that technology is locally supported, the system is likely to fail, and the application probably will not be sustained after the departure of foreign experts.

5.1.3. Longer Lead Times. Current generation computer systems and commercial software are easy to install, and to many, installation has become the benchmark of a successful application. Unfortunately, installation of software and hardware are the least difficult aspects of implementation. Training, data base formation, and understanding and correctly using the information products produced by the system take much more time and effort. Recent experience indicates that, to transfer planning applications, extensive training in both computer operation and in analysis of the output information products is needed. Substantive training requires three to five times longer than training to operate the computer. Also, information systems take longer to successfully implement in developing countries because of the lack of computer infrastructure and local sources of expertise.

5.1.4. Direct Transfer of Applications. Most information systems and planning applications used in development have been transferred with little or no modification from developed countries. This direct transfer of technology does not account for local differences in physical environment, infrastructure, planning resources, or objectives. It is debatable how relevant many of the applications are to conditions in developing countries and to their current planning processes. Personnel involved in the transfer of technology and the development of information systems must become more sensitive to local requirements and try to modify or develop software that more closely meets local, developing-country requirements. Review of systems in use in developing-country planning offices has shown a marked decrease after foreign experts, who installed the systems, departed. This lack of sustainability by local planners may be caused by local technical and training problems, but just as often, the cause is that the application has been transferred without a clear understanding of local information requirements and/or administrative systems.

5.1.5. Training. Another key to successful implementation is making sure that the end user knows what his role is in the information system. Too frequently, systems are defined without reference to the individual who inputs the data or uses the information products. Those people are a critical part of any information system and a major reason why systems fail. End users cause failure when they find that the system creates more problems than it solves, or they do not understand the purpose of the system or how to use it. Just as software must be appropriate for the application, so must the user's knowledge of how and why to use the application. The transfer of those skills can only be accomplished through intensive and continuing training of the end users. The more training that is provided, the more likely the application is successfully absorbed into the planning process. End-user training is expensive and time-consuming, but it is critical to successful implementation. Agencies should expect to expend at least 20 percent of their information systems' budget on training. Training also should be ongoing and aimed at spreading computer literacy and skills, even

to parts of the organization that have not been automated. This will provide a pool of trained people to replace those who leave the organization.

5.2. Choices. Planners in developing countries face difficult choices concerning what type and scale of information systems and technology to use in their organization. Ignoring information systems will not make them go away, and as awareness of the potential benefits of using information technology grows, more pressure from the political sphere will be exerted for its use in development planning. Planners should begin to use the technology as they would any new tool -- with care. Information systems will not alone solve planning problems that confront developing-country planners, but the systems can provide, if properly implemented and used, better information products on which to base plans and development decisions.

6. BIBLIOGRAPHY -- Information Systems Applications in Regional Planning

This report is largely based on the author's experience with information systems and information technology in developing countries for the last 15 years. The following references are provided to assist the reader in gaining a better understanding of computer technology and different perspectives on information systems applications for development.

Assessing and Selecting Local Area Networks, Sparta, NJ: Office Futures Now, Inc., 1986.

Barb, Charles E., Jr., "User-Oriented Data Base Management Systems and Their Selection," Computers, Environment and Urban Systems, 1984, Vol. 9, No. 4, pp.247-258.

Berge, Noel, Marcus D. Ingle and Marcia Hamilton, Microcomputers in Development: A Manager's Guide, West Hartford, CT: Kumarian Press, 1986.

Coiner, Jerry C., Ignacio Armillas and Vincent Robinson, "Microcomputer Spatial Data Bases for Human Settlement Planning," in P.S. Gaeser (ed.), Data for Science and Technology, North-Holland Publishing Co., 1983, pp.198-204.

Coiner, Jerry C., "Microcomputer-Based Development Control Administration in the Town Planning Department, Jamaica" in Peter Van Demark (ed.), Papers From the Annual Conference of the Urban and Regional Information Systems Association, 1987, Vol. 3, pp.21-29.

Considerations for Use of Microcomputers in Developing Country Statistical Offices, Washington, DC: International Statistical Programs Center, 1983.

de Man, W. H. Erik, Conceptual Framework and Guidelines for Establishing Geographic Information Systems, Paris: UNESCO, 1984.

Goodchild, Michael F. and Valerian T. Noronha, Location-Allocation for Small Computers, Iowa City, IA: The University of Iowa, 1983.

The Guide to Software for Developing Countries, Paris: IBM Area South, 1985.

InfoTEXT - The Newsletter for Computers in Planning, Akron, OH: The Information Technology Division - American Planning Association, various dates, various issues.

Josin, Gary, "Neural-Network Heuristics," Byte, Vol. 12, No. 11, October 1987, pp.183-192.

Kernighan, Brian W. and Dennis M. Ritchie, The C Programming Language, Englewood Cliffs, NJ: Prentice-Hall, Inc., 1978.

Kingsley, G. Thomas and Sarah W. Wines, Town Planning and Land Development in Jamaica: An Agenda for Reform, Washington, DC: The Urban Institute, 1987.

Klosterman, Richard E., "An Assessment of Three Microcomputer Software Packages in Planning Analysis," APA Journal, Spring 1986, pp.199-202.

Klosterman, Richard E., Microcomputer Technology and Regional Planning, Akron, OH: Department of Urban Studies, University of Akron, June 1987.

Kruglinski, David, Data Base Management Systems, Berkeley, CA: Osborne McGraw-Hill, 1986.

Landis, John D., "Electronic Spreadsheets in Planning," APA Journal, Spring 1985, pp.216-224.

McClure, Carma, "The CASE for Structured Development," PC Tech Journal, Vol. 6, No. 8, August 1988, pp.50-67.

Microcomputers and Their Applications for Developing Countries, Boulder, CO: Westview Press, 1986.

Mirecki, Ted, "Enter OS/2," PC Tech Journal, Vol. 5, No. 11, November 1987, pp.52-63.

Newton, P. W., and M. A. P. Taylor, Microcomputers for Local Government Planning & Management, Melbourne: Hargreen Publishing Co., 1986.

Newton, P. W., M. A. P. Taylor and R. Sharpe (eds.), Desktop Planning, Melbourne: Hargreen Publishing Co., 1988.

Obermeier, Klaus K., "Natural-Language Processing," Byte, Vol. 12, No. 14, December 1987, pp.225-232.

Ottensmann, John R., BASIC Microcomputer Programs for Urban Analysis and Planning, New York: Chapman and Hall, 1985.

Rich, Charles and Richard C. Waters, "Automatic Programming: Myths and Prospects", Computer, August 1988, pp.40-51.

Robinson, Vincent B., Development of an Urban Information System Unit at the Urban Development Authority Colombo, Sri Lanka, Colombo: Urban Development Authority, 1982.

Robinson, Vincent B., and Jerry C. Coiner, "Characteristics and Diffusion of a Microcomputer Geoprocessing System: The Urban Data Management Software (UDMS) Package," Computers, Environment and Urban Systems, 1986, Vol. 10, No. 3/4, pp.165-173.

Sawicki, David S., "Microcomputer Applications in Planning," APA Journal, Spring 1985, pp.209-215.

Shorter, Frederic C., David Pasta and Robert Sendek, Computational Methods for Population Projection: With Particular Reference to Development Planning, New York: The Population Council, 1987.

Taylor, Charles F., Jr., Master Handbook of Microcomputer Languages, 2nd edition, Blue Ridge Summit, PA: TAB Books, Inc., 1988.

URISA News, Washington, DC: Urban & Regional Information Systems Association, , various dates, various issues.

Whited, William L., Using Microcomputers in Urban Planning, Chicago: American Planning Association, 1982.