TECHNOLOGICAL CHANGE AND MANAGEMENT INFORMATION SYSTEMS

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Abstract

This paper describes the key elements of technologically-based change to be faced by corporate Management Information Systems and discusses the strategical issues related to corporate MIS management that will arise over the next 10 to 20 years.

1. Introduction

The objectives of this paper are twofold: first is to describe the key elements of technologically-based change to be faced by corporate Management Information System (MIS) over the next 10 to 20 years, secondly to discuss the strategical issues related to corporate MIS management that will arise over this period.

Corporate information systems evolved in parallel to information processing technologies. Table 1 displays the main hardware/software elements that characterized the evolution of data processing.

Often, the absence of sufficient hardware power defeated well thought and well needed information concepts. The concept of "integrated information systems" came prior to the advent of large scale storage and local area networks that could make it possible. Many applications in Artifical Intelligence and Expert Systems came into being prior to the existence of expert shells, LISP computers and supercomputers. Therefore, management must proceed with caution when implementing concepts advocated by system developers.

On the other hand, the adoption of technology, or its state-of-the art utilization, made some business dominant in their area of activity. For example, the SABRE airline reservation system placed American Airlines in a position of leadership, the "Wizard of Avis" did the same for Avis Rent-a-Car, and the development of large digital switches placed AT&T in the leadership and dominance of the telephone equipment market.

Data processing systems evolved from primarily computing devices to complex systems that serve as the main information storage and communication elements for the corporation. MISs can be classified either as Electronic Data Processing Systems (EDP) or Decision Support Systems (DSS). Data Processing Systems and Decision Support Systems, are compared by Alter[1], and a modified version of the comparison is presented in Table 2.

A common area for DSS and EDP systems are the standard reports prepared on a regular basis for decision making. Decision support systems may be classified as : (1) decision aids, (2) non-expert DSSs and (3) Expert Systems[2]. We shall first introduce the evolution of the computer development in historical terms, then we will discuss some key technological developments that will affect MISs to come, the following section will discuss the expected changes in these socio-technical systems, and the last section will deal with change, coping with change, and main conclusions from this discussion.

2. Key Elements of Technological Change

Important developments with great potential impact on the structure of information systems technology are occuring in hardware, software, peopleware and communication technology. These changes, and their integration into corporate MISs will determine the shape of future information systems.

2.1 Computers,Microcomputers and Workstations

Many consider[3] the first computer that somewhat resembles modern computers to be ENIAC, developed at the University of Pennsylvania, first used in production calculations for the Los Alamos Laboratories, in 1945. The ENIAC, occupied 15,000 square feet, had little storage capacity and was programmed by plugging and replugging some 6,000 switches.

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1. This work was performed while at the Graduated School of Business, Columbia University.

This technical development allowed the design of the EDVAC[4] a more advanced machine that eliminated the switcheks and had more memory and a series of more advanced technical developments.

The first Univac computer was delivered on June 14, 1951.[5]

"For almost five years it was probably the best large-scale computer in use for data processing applications."

In 1953 IBM delivered its Defense Calculator 701 and soon after a commercial version the 702, substantially inferior to the UNIVAC machine. The 702 was soon followed by the 705, that featured the new magnetic core memory developed at MIT. In August 1955, UNIVAC had thirty large computers installed while IBM had twenty-four. One year later, IBM had seventy-six of its big machines installed to Univac's forty-six, with three times as many machines on order.[3]

A computer typical of the early sixties would be the Burroughs 205. It had 8K of magnetic core, used punched paper tape as input device, had assembler language and later in its life a'lowed programming in FORTRAN. It occupied about 2,000 square feet and required very elaborate air conditioning.

These early systems made MIS's oriented towards intense processing applications aimed at replacing computation oriented types of manual processes. The first major victories of computers in the organization related to very labor intensive natural applications as billing for utilities, payroll, etc.

The sixties and seventies[6] presented more and more sophisticated computing, first with the incorporation of inexpensive sequential storage and random access storage, allowing the functions of corporate data storage to be incorporated to computers and second with the advent of multiuser systems with "time-sharing" and teleprocessing where communications were aduea as an additional functional capability. The commercial demand for computers of all sizes led to the appearance in the market of a wide range of computers from mainframes and supercomputers to multi-user minicomputers.

The introduction, in the late seventies and early eighties, of commercially viable microcomputers substantially changed the computer environment. Early microcomputers could be characterized along the following capabilities:

-memory 16 to 64 kilobites

-processing speeds of approximately 0.1 MIPS

-low speed disk storage of several hundred kilobytes

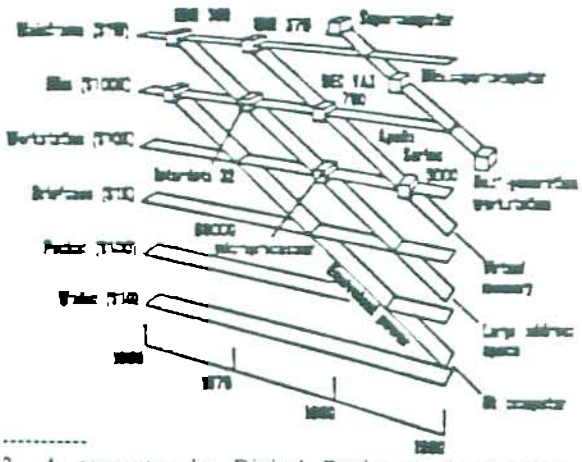
-command driven, non-graphic iterfaces

The development of microcomputers created a first stream of pressures on the mainframe world requiring improved user interfaces and easy-to-use softwares. Furthermore developments in chip technology (LSI - large scale integration) and the advent of this very large mass market for chips allowed the large mass production of chips at a price prior inconceivable to designers. This changed dramatically the balance of costs of the components of data processing equipment. Their logical elements (CPU - central processing unit and other chips) became inexpensive in relation to other elements allowing for the development of workstations with mainframe power at a price range between micros and minis.

Workstations are full 32-bit computers usually with sophisticated graphics displays, a keyboard, and a mouse, and usually attached to a high-speed network. These allow the performance at the local level of highly-complex and computer intensive functions as engineering design, actual analysis, mathematical modeling, advanced graphs, etc. For less than $20,000 a user can have 1.4 mips workstation, with up to four mefabytes of memory, a 72-megabyte hard disk, and a color graphic display that is 1024 lines by 800 columns. Such performance is equivalent to a medium size VAX[2] computer. Workstations are now being offered by Sun, Apollo, Digital Equipment (micro VAX) and Hewlett-Packard (HP 9000 series).

Bairstow[7] discusses the past and the future of computer technology and quotes David Nelson of Apollo Computers in classifying computers into seven tiers, each separated from the other by a factor of 10 in cost. The aggregate improvement in performance across the tiers is about 35% a year, so a tenfold improvement (across one tier) occurs every seven years. This chart is displayed in Figure 1.

Figure 1. Downwards Migration of Computer Technology[3]



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2. A computer by Digital Equipment Corporation, currently the de facto standard for engineering and scientific computers.
3. Source, Apollo Computers.
4. Sun[8] is the world's leading supplier of technical workstations. It has just recently lowered the price of its entry level system, the Sun 3/50, to $4955, classifying in clearly as a microcomputer, not a higher level (and price) workstation. For taht price the user gets 1.5 MIPS (Millions of Instruction Per Second), built-in Ethernet capabilities, one of the best versions of UNIX, network file management systems, and a 19-inch monochrome monitor.

R&D of Sun Microsystems, in making predictions about the future of wokstations. These are reflected in Figure 2 where processor speeds, memory size and display memories are projected into the future.

Figure 2. Future Workstation Performance[5]

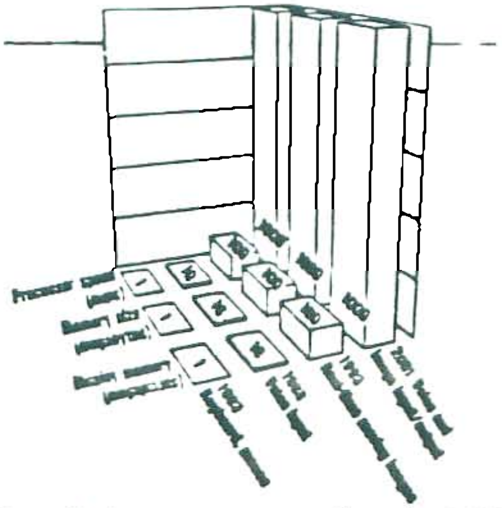

Figure 2 shows a new generation of workstations starting in 1988, using RISC (reduced instruction set computing) technology beginning at about 10 mips in 1988 and exceeding 100 mips by 1992. The 1992 workstations will have programmable graphic processors to display complex curved surfaces with realistic lighting and shading, and to show documents with presentation-quality graphics. They should be able to handle moving images in real-time. Networking via fiber optics will allow real network capabilities and full sharing of peripheral resources. Such machines will be powerful enough to use artifical intelligence techniques whenever appropriate.

By the year 2001, $1500 (in today's dollars) will buy a truly cognitive machine with such good voice and image input/output that a keyboard will no longer be necessary. "Such a machine," continues Joy, "would have at least 24 color planes and could show complex images at movie speed [24 frames per second], maybe with stereo sound display."

Many experts predict that due to their productivity gains workstations should be the most common mode of computing in the business world within ten years. The consequences to business computing and MIS are immense. Many applications will run at a local level collecting data and performing most posting and editing applications. The aggregation function will be kept at the central level as well as the interdivisonal and interfunctional report generation functions. On the other hand many reporting and local management information will be kept at the local level and never be brought to the central location. The consequences in terms of management style, control, productivity and data custody are potentially considerable.

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5. Source, Bill Joy of Sun Microsystems quoted by Bairstow[7]

2.2 Storage and Communications

As in many other areas of computing, IBM tends to be a late arrival, but can rapidly assume command of sales. In early 1986 it announced its RT PC aimed at the higher end of the micro market and to be used mainly as a modest engineering workstation. By March 1987 it had only sold about 5,000 of these units[6] when it announced its entire new lineup of[9] microcomputers called the "Personal System/2". In the higher end of this series it recognized the workstation market with the PS/2 Model 80 costing in the $7,000-10,000 range and offering a performance of about 8 times the PC/XT model. This model presents a new operating system, memory expandable to 16 Mb and fixed disks up to 230Mb. As a peripheral device, IBM announced an optical disk device, using WORM (write once, read many) technology. Each disk holds about 200 megabytes of information, and the model 80 can take up to 8 of such disks (1.6 Gb, gigabyte). This storage capacity would be grossly the equivalent of 2 million pages of text. This storage capacities at the individual user level has major implication for the nature of future systems.

In order to get an understanding on the role of storage technology we must examine its historical development. The advent of magnetic tapes, as a computer device, changed the emphasis of data processing from phase 1 to phase 2 as described earlier in Table 1. Data storage costs, for sequential data usage, were low but ready access to data was very limited. With the advent of multiuser computers and the incorporation of communication as a main part of data processing, directly addressable data became of great importance. Consequently online storage in the form of magnetic disks and drums became of essence. This allowed the development of large applications as airline reservations, large telephone switches, strategic air defense systems as well as the more mundane online applications for data entry and business file maintenance. The advent of the "Winchester" type disk drives made disk devices much more reliable and brought their cost down to be affordable in microcomputers.

For many years, data communication over telephone lines required a modem transmitting character data at 300c baud (roughly thirty characters per second), without error detection or correction facilities. Modem speeds have now jumped to 2400 and 4800 bauds and are to go higher soon. A variety of communication protocols made it possible to transmit data virtually without error. Currently a large number of both public and private packet-switched networks are in place or being installed. Such networks typically are equipped with gateways to other networks.

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6. Source, International Data Corporation

For example let us examine corporation XYZ, a major manufacturer of electronic equipment. The company has a series of mainframes connected a front-end communications processor that through satellite communications and microwave dishes talk to each other at 56 kbps. Locally the communications and microwave front-end machine communicated with a series of terminals and microcomputers at 9.6 kbps in a local communications network. In addition the front-end machine is connected to a multiplexer that is connected to another multiplexer communicating at 1.544 Mbps. At the second multiplexer a gateway machine connects a local area network as well as a public network such as ARPA or bitnet. Furthermore, many mangers use telephone lines, dialing directly out of the Mainframe to connect to information utilities as Dow-Jones News Service, the Source, etc.

2.3 Expert Systems and Artifical Intelligence

"After year of development and considerable delays, applications making use of Artifical Intelligence are finally reaching the desks of everyday computer users."[10]

Artifical Intelligence (AI) is a broad-based technology that encompasses work in fields such as natural languages, language translation, computer vision, speech recognition, and expert systems. The last field expert systems[11] is the one that presents most promise for MIS.[12]

"Expert Systems are sophisticated computer programs that manipulate knowledge to solve problems efficiently and effectiv@ly in a narrow problem area. Like real human experts, these systems use symbolic logic and heuristics- rules of thumb- zo find solutions. And like experts they make mistakes but have the capacity to learn from their errors."[13]

Expert systems (ES) are being used in a wide range of applications in accounting, computer systems and auditing. DEC uses expert systems to configure its VAX computers, to help salesmen in their sale, and to estimate delivery schedules. Coopers & Lybrand, a major CPA firm uses an ES in the evaluation of a client's tax accural. Peat, Marwick & Mitchell another major CPA firm uses an ES to assess the loan portfolio of a bank.

MISs will be greatly impacted by expert systems. Despite the fact that substantial expertise is already impounded into MISs, this is only the tip of the iceberg. The entire balance of what a system does, what its developers decide, what the users request, and what manual interaction is expected in the system will rapidly change. Table 3 presents a series of potential effects of ES over MISs.

It is difficult to predict the order and potential of arrivals in this area, but it unquestionable that labor intensive efforts as MIS design, implementation, and operation will be substantially affected by AI and ES.

3. Trends and New Technology in MIS

3.1 Centralization vs Decentralization

Traditional large-scale storage and retrieval systens are configured around a very large mainframe computer at a central site where all data is stored and mainatained. The mainframe provides access to the data on a time-sharing basis. Users access the system via dumb terminals connected to the mainframe in some fashion. All database creation, alteration, manipulation, and reproduction is done in the mainframe.

The main effect of the changes earlier described in the hardware and storage technologies will be the distribution of many MIS functions along the functional lines. Local workstations may collect and store data, using very sophisticated user interfaces, very heavy in computational requirements, that prior could not be performed except at a mainframe. Local server storage units may be set up to serve one single LAN where many workstations serve as data collection and user interface and query locations. Non-local queries may be handled by high speed interface between different clusters and the core of the network or different gateways in fully distributed networks.

3.2 Data Processing at Several Levels

Users will enter data and perform MIS functions at the lower level delivery device. The system software will make the decisions as to at what level the data processing, storage and aggregation will be performed as well as when the result will be transmitted to other devices. As fas as the user is concerned these levels of computing will be invisible.

3.3 Data Capture

Current and emerging MISs are progressively attempting to capture data at the moment of the economic transaction. Such capture, automatic or not, permits improved data preparation controls, decreased in data entry costs and the capture of substantially finer event information. Emerging MISs will use a wide variety of data collection devices ranging from automatic monitoring and measurement of the machinery (probes and measurement tools), user activated data collection (e.g. ATMs) and the use of a wide variety of entry-facilitating devices as touch-screen terminals, voice input, bar scanning, etc.

3.4 Common Editing Facility

The advent of large local data processing facilities allows for the localization of complex data editing facilities located at all system entries allow for coherent and homogeneous data scrutiny, feedback and reevaluation for parameters based on actual errors found and substantially decrease error correction costs.

3.5 Localized Report Generation Facilities

Local workstations that collect data will serve also as local MISs with report generation facilities that in earlier systems were exclusive to the central facility. Consequently, for example a supermarket chain, will collect data at local cash registers, edit data at a local server, prepare local reports at the local server, flush data aggregates at pre-set times of the month and always be available for queries from the central and other facilities through data networking facilities.

3.6 Local Decision Making and Decision Taking Features

The facilities described above linked with expert system capabilities may allow for software-based decision (decision making systems) and their implementation (decision taking systems). These dicisions, most likely will only involve the simpler judgements where consistency is of great value.

3.7 Aggregation at the Local and Central Levels

Most modem database systems will post entries at the moment of data entry as well as posting values to higher level aggregates being kept. Future systems will continue this trend but keep local aggregates to support local reporting and decision making.

3.8 Online vs Batch Posting

Most future systems will perform updates at collection time. The enrichment of processing and commnication facilities may imply on "shadow posting" of transactions and their judgement on a background basis or the reperformance of the posting in a batch mode.

A blueprint of future systems would entail on collection of a much wider set of variables and their storage at a distributed level. A common chart of accounts and the breakdown of the different levels of reporting also table driven allows for the distributed storage at a very fine level. Intermediate and central processing would act primarily on higher levels of aggregation.

3.9 Continuous Auditing and Management Traces

Most future MISs will have impounded audit modules for auditor continuous monitoring as well as sufficient control and monitoring points for management retracing of transactions. The level of aggregration and difficulties of balance and transaction tracing that are prevalent in current systems will decrease as processing economies that dicated the limited traceability of transactions will not be needed in future more powerful systems.

4. Conclusions

Despite the great changes that occured in the last thirty years in computer technology, MISs resisted changes in basic structure. Many corporations still run the same basic systems that were run in their early computer days.

The research and development of technology as well as its placement in the marketplace are just the beginning of the longer process of behavioral acceptance of technology and its actual absorption into socio-technical systems. Behavioral resistance to change[14] is the major delay factor in the computerization of corporate processes. It is only now, thirty years after the first business computers were placed in organizations, that they are fully accepted in the management process.

Consequently the process of change, due to the introduction of technology, must be managed. Among the often proposed steps we find:

- Create the formal function of managing the introduction of technology
- Facilitate and require technical updating to technical personnel
- Create facilities for technical illustration for non technical personnel
- Do systematic reviews of technological status at regular periods
- Require competitive reports of technological status and cost comparisons for the organization vis-a-vis the competition
- Stimulate the free flow of ideas with partiular emphasis to innovation
- Estimate a program of technological watch

In addition to the issues of technological absorption, particular technological events were discussed. The early days of computing found improvements in processor power of major importance. These changed the nature and power of computing progressively incorporating to the original processing functions of EDP systems, the functions of storage, communication, databases, workstations and decisions. These changes made MISs evolve from pure EDP systems to DSSs with maybe expert capabilities.

The technologies that will mostly affect MISs in the next year are workstations and mass optical storage. Managers should also watch for the emergence of parallel computers[15], computer based manufacturing integration[16], and optical computers[17].

Corporate MISs in the future will: 1) be more decentralized, 2) process data at different levels, 3) capture data close to the economic event, 4) benefit from common editing facilities, 5) have localized report generation facilities, 6) allow for aggregation at different levels, 7) have online-real time transactiob posting, and 8) continuous audit monitoring with mechanisms that allow for transaction tracing at any level of aggregation.

TABLE 1. The Evolution of Data Processing

Phase	Years	Functions	Other
1	45-55	Input(I) Output(O) Processing(P)	
2	55-65	I,O,P Storage(S)	Magnetic Tapes Natural Applications
3	65-75	I,O,P,S Communication(C)	ing Systems Disk Storage Expanded Operations Support
4	75-85	I,O,P,S,C Databases(D)	Integrated databases Decision Support Systems (decision aids) Across-Area Applications
5	86-91	I,O,P,S,C,D Workstations(W)	Networks Decision Support Systems (non-expert)
6	91-on	I,O,P,S,C,D,W Decisions(De)	Decision Support Systems (expert)

TABELE 2. EDP vs DSS

	EDP	DSS
Use	Passive	Active
Activities	Clerical	Line, staff and Management
Orientation	Efficiency	Effectiveness
Focus	Past	Present and Future
Emphasis	Consistency	Flexibility
Frequency	Regular	Ad hoc
Mode	Batch & Online	Online
	Transaction Processing Record Keeping Business Reporting	Decision Making Decision Implementation

TABLE 3. Expert Systems and MIS

Expertise	Function
Error Correction	Replacement of Clerical Efforts
Load Balancing	Using the communication network to allocate data processing
Data Balancing	Using the communication network to allocate data in a distributed database
System Monitoring	Using pattern recognition to anticipate system facilures
System Integrity	Using pattern recognition to scrutinize or fraud
	Evaluating system accesses for unauthorized systems
Hardware Configuration	Evaluating bottlenecks and reconfiguring systems
Network Management	Evaluating node usage for hardware enhancement
Interfaces	Interfacing with functional expert systems
Software Design	Software for application design
Programming Errors	Self correcting software
Database Management	Software to management of databases and design of logical structures
System Interfaces	Software for database redundancy analysis

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