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THE MANAGERIAL AND ORGANIZATIONAL CONSEQUENCES OF SMALL SCALE COMPUTER SYSTEMS
A Cooperative Pre-Research Study

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PREFACE

This collection of papers is written by the participants in a workshop held at IIASA. It is thus not only a collaborative paper but also a conference proceedings in the true sense of the word. It thus differs from many conference proceedings which present a collection of papers tabled at a conference but which do not seriously describe what happened at the conference. It is not therefore a collection of reporting of individual research; it is a pre-research study leading to individual research and to other collaborative work. Nevertheless, although there is little here that is "new", we feel that the importance of the subject is such that the findings of the workshop should be made available to a wider audience. One reason for this is to encourage wider collaboration between IIASA and research teams working in this subject elsewhere. The research already planned envisages collaboration with research teams in the U.S.A., U.K., Japan, Czechoslovakia, Hungary and the U.S.S.R. Collaboration with other teams actively engaged on studies of the impact of small scale computer on management and organization would be welcomed.

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INTRODUCTION

R. Tomlinson

Background

No one questions the fact that computers have already made a great difference to our personal and organizational lives. But in most cases the impact, however serious it may be, is indirect. Because of computers we can book airline tickets at almost any place at almost any time. Because of computers, we find that small faults in bureaucratic systems cannot be rectified because "it is all done by computer". Because of computers some people have new jobs and some people now have none. In none of these cases, however, does the individual concerned have a personal contact with the computer. Often it is only because he has to fill in a form in a different way that he is aware that the computer is involved at all. If one looks at what happens in offices and organizations one has the same feeling. Although the computer provides an overwehlming, even menacing presence in the background, few of those engaged in clerical work have direct contact with it. Most managers never see it. They are aware that there may be advantages to the organization as a whole, but the immediate effect on themselves is largely one of convenience. Their working pattern is unaltered, and the organization in which they work retains the same basic structure as before.

It is likely that this will change in the next decade. Mini- or microcomputers have already had a major effect on process control, on equipment design, on office routines and procedures. We are just beginning to see the first glimmerings of what it will do to managers' actual tasks, to the way they approach their problems, to the way they are organized. It seems inevitable that the changes will ultimately be very great. The low cost of small scale computers, in particular the low cost of storage, will mean that the main barrier to their widespread use will be the conservatism of the people concerned and in restrictive administrative practices. One of the most important new developments will be the use of small scale computer systems as an "on-line" aid to thinking and planning. An illustration of what may be in store can be seen from a typical experience in introducing simple budget models on to interactive terminals. In one such case these models were introduced as a means of carrying out quick checks on the historical-financial position. However, the managers concerned quickly saw that if they turned the model around, using forecasts rather than historical data, they had a planning tool which was ideally suited to the exploration of the consequences of possible alternative actions. In the past the time limitations imposed on planners were such that they had little time for exploring alternatives. They had had to guess a convenient plan, quickly undertake the necessary financial calculations, and then check that it gave satisfactory answers. If the plan had to be changed at short notice there was no chance to explore alternatives. Suddenly, by the use of terminals the whole pattern of planning altered almost overnight. Planning became analytical rather than guess-work; last minute changes to plans were handled with precision, rather than through the introduction of ad hoc adjustments whose consequences could never properly be evaluated. Just how far may we expect such changes to go in the future?

The change on managers--in their thinking and in the way in which they do their work--may be the most critical effect of the mini-micro computer revolution, but the consequences will be much more widespread than just on the individual. There are major potential consequences on organization, on training, on employment itself. These consequence will feed back to the technological problems, for example, in connection with network design and on software. In the long run the whole management information and control structure will be transformed, possibly in a way that makes the present body of knowledge irrelevant.

These are systems problems arising out of the impact of technology, and are thus particularly relevant to the Management and Technology Area of IIASA. It is a field whose exploration needs the involvement of specialists from many fields of activity, whereas most studies in this area have largely been unidisciplinary. When therefore the Management and Technology Area was developing a new program at the beginning of 1978 it was agreed that this was a topic that was ripe for a "pre-research" study. Preliminary discussion showed however that few, if any, individuals were competent to prepare an adequate review of a subject which required information from so many separate specialities. It was accordingly decided to organize a workshop with invited participants from many countries and many disciplines. These papers present the results of that workshop which was held at IIASA from 26-28 September, 1978.

Outline of the Workshop

Nine countries and two international agencies were represented as can be seen from the list of participants attached at the end of the document. Individual specialist interests ranged from sociology and economics to hardware development, and the interaction that arose because of their diverse knowledge of computer application proved to be one of the most exciting features of the workshop. As a preparation for the conference Dr. Tibor Vasko had prepared an introductory paper which was used as the basis for the initial discussion and thereafter the meeting broke up into four groups, each of which were concerned with a separate aspect of the subject. On the second day each group made a preliminary presentation of its ideas to the rest of the team and, following the comments received, prepared a written statement. Some of these statements have since been revised further as a result of additional work on the part of one or more participants in the group.

The first group was concerned with technological developments. They were presented with two main questions to consider, namely: (1) what are the main technological developments that will appear over the next five to ten years as seen by the user, and are they caused by economic pressures or by the pressures of internal convenience; (2) what is the likely rate of diffusion for such developments and what are the main factors affecting their progress. In connection with this the group was asked to consider whether the topic was already adequately covered by research and if so what were the key references. They were also asked to think about any notable gaps and the way in which they might be filled through IIASA coordinated research. The findings of this group have been absorbed into the original Vasko paper and this revised draft follows this introduction.

The second group was concerned with management tasks. It was also provided with two main issues to consider, namely: (1) in what way will managerial work be modified by modern computer development; (2) what is the likely rate of diffusion of these changes and what are the main factors influencing the more rapid spread of these new ideas. The findings of this group have subsequently been commented on and revised by the team members and are set out in section 3 of this volume. However it was also felt that there was a need for a more thoroughgoing research paper and it was arranged that the authors should meet again at IIASA to prepare this.

The third group was primarily concerned with the impact of small computer technology on organization. This proved much the most difficult subject to treat as a matter of substance. Organizational problems are different from one country to another and depend to some extent on the sophistication of the existing organization. (This is therefore a potentially important and fruitful area for research.) The report of this group, set out in section 4, is perhaps deceptively the shortest of the reports.

The final group considered the social impacts of small computer systems. This also proved a difficult area to summarize since although all countries were concerned with social impact they felt that they had essentially different grounds for concern. Basically the Western countries were concerned with job shortage, the Socialist countries with personnel shortage. A general review of their conclusions has been prepared by Ernest Braun and is published as section 5 of this volume. It is hoped too, that this exchange of information and ideas will lead to further basic research papers.

All the groups were asked to consider the question of a future research program and the need for further and possibly more widely based conferences on the subject. It was generally agreed that the time had come for work rather than talk, and there was little encouragement for the preparation of further conferences at the present stage. These proposals were analyzed and reconstituted by Göran Fick who has since joined the staff at IIASA to coordinate our research. His review of the program is set out as the final section of this paper. The first table lists all the major proposals for research or for conferences that were made and the final diagram sets out the proposed research plan.

Conclusion

There are few more exciting moments than when a group of research-minded scientists meeting for the first time suddenly take fire from the ideas presented by their colleagues. These papers represent the glow that is the aftermath of that initial conflagration. It is our task at IIASA, together with collaborators from industry and from research institutes throughout the world, to fuel the fire with resources and fan it into flame with the wind of encouragement. We are considering one of the major problems that society must face in the next years. We cannot neglect it.

SOME CONSEQUENCES OF TECHNOLOGICAL DEVELOPMENT ON SMALL COMPUTER SYSTEMS

An introductory paper for the IIASA Workshop by

T. Vasko

This is a revised version incorporating the Workshop group comments by

U. Shaff and P. Weber

The International Institute for Applied Systems Analysis is studying important technological developments and their impact on society as a whole or on parts of it.

The revolution in the technology of semiconductor devices in recent decades has caused a spectacular development in computer systems. In the past few years it was the mini and micro systems which seemed to emerge as the fastest growing computing arsenal for institutions, organizations and even individual persons.

With the thought that this development might be of interest to several of IIASA's national member organizations, the Management and Technology Area is undertaking a study of managerial and organizational consequences of mini and micro systems.

Some Relevant Facts of Mini and Micro Computer Development

One has to start with semantics. Here we are faced with two complications:

-- First, the boundaries between mini and micro and between mini and "midi" are not fixed but are moving fast with technological development when measured or fixed by performance. In the past six to seven years the performance/price index was improved by an order of magnitude. If we take into account the present trends of increasing computer power and decreasing cost, the future generations of minis will be comparable to some of today's maxis in capacity and performance.

-- Second, in spite of the relatively short life-span of this technology, there is a wide spectrum of mini and micro computers without any accepted scale within the spectrum. Therefore the abbreviation mini/micro (M/M) has been found reasonable.

Generally speaking one can question the validity of the terms mini and micro computer. It is difficult to find features which are mini or micro except, perhaps, for the price.

Here are two of the definitions of a mini computer which are perhaps most apart:

-- The mini computer, with few exceptions, has been nothing more than a system component... (Cay Weitzman) [1];

-- The mini computer--a universal computer, which, similar to a big computer, can perform operations of computing, analysis and processing of data, data collections, control, etc. (A.V. Kutzenko, B.A. Polosjanc, Ju.V. Stupin) [2].

There are many different definitions but the difference may be more apparent than real.

Mini computers emerged in the late fifties and were applied to many different areas. Since then they experienced an explosive growth. The estimates were $300-450 million in 1972, $800-1,400 million in 1975 and $1.8 billion in 1977 (Datapro Research Corporation). These figures include the rapid decrease in the cost of central processors. This fast growth even caused concern and speculations that this growth can be self-destructive [3]. Some others argue that success of mini computer applications has never been comprehensively surveyed [4].

Micro computers were created by the progress of a semiconductor technology which in the early seventies led to the possibility of manufacturing the whole processor function on a single chip of silicon. This was the first micro-processor. Since then this technology has manifested a spectacular development, bringing a new generation of micro-processors every two years. This policy seems to be secured for several years to come, but there are certainly limits to the present technology. It is not easy to predict the possible development too far beyond the limits of existing technology.

Speaking of the economy of using M/M computers, it is the decreased price of computation, not of computers, that matters. M/M computers decrease the total cost of solving a computational problem, so that the cost of hardware represents only a small (and decreasing) fraction of it. Principally the M/M computers cannot solve any problem the bigger computer cannot, but can deliver the solution more cheaply, thus making the power of the computer more easily available. A case in point is the personal and/or home computer. The importance of this type of computer can be derived from the fact that all major suppliers of big computers have started the production of mini computers. Some even made agreements with the manufacturers of micro-processors and LSI components (for example IBM and INTEL).

M/M computer systems are becoming more and more complicated, but their low price has enabled construction of more complex systems where one or more M/M computers represent building blocks of the system, each micro-processor having dedicated functions. This new feature has been strongly pronounced in recent years.

When M/M computers are connected through appropriate circuitry to real processes, they can monitor, measure and control various parameters of the process and, because of their small physical size and power consumption, they can be integrated into the control equipment.

This is particularly true of micro computers. It is estimated [5] that in similar applications micro computers are substituting for:

-- sequential logic control circuits in 56% of all applications;
-- mini computers in 12% of applications.

New applications made possible by better performance/cost ratio count for 32% of all applications. This distribution of applications is not unique and is changing in time. Some figures are given for example in Electronics Industry [6]. This is the technological base of wide applications of M/M computers in manufacturing industries (NC, CNC machines, textile machines, etc.), laboratory and medical equipment and also in mass produced consumer equipment such as personal cars, washing machines, electric ovens, TV sets, etc.

This feature also has had its impact on computer systems. The use of M/M computers in computer terminals created the so-called "intelligent" terminals with greater flexibility and also some processing capability. They represent a prevailing instrument for man-computer interaction.

The low price of M/M systems led to the design of problem-oriented or functionally specialized systems. The interconnection of such systems results in many architecturally interesting systems which permit the construction of still more powerful and cost-effective systems.

Even if, from an architectural point of view, we construct a computer network by the interconnection of computers, intelligent terminals and other equipment, it is still the appropriate software which will make it function as a real network. The importance of this design principle is in the fact that it seems to limit the validity of Grosch's Law (1953), which states that the power of a computer system increases relative to the square of its cost. Grosch's Law is based on the economy of scale which holds to some extent for the CPU and the memory. The advantage of mainframe universality has a drawback in the increasing complexity and overhead in securing the high use of CPU and memory time. With the advent of cheap M/M systems it is the economy of problem orientation (perhaps specialization) of M/M computers which counteract Grosch's Law.

The "genetics" of M/M computers can be traced down to the very root of new developments; it is the component innovation. Therefore it has an influence on all the subsequent stages of computer development and use. This may be the reason why the recent spectacular development of M/M computers in some way "reinvents" the past development of computer technology. It is true that by the invention of the transistor a universal device was created which was used for many purposes (to amplify, control, process information, etc.). On a different level of complexity, micro-processors represent a similar universal device [7]. Development of the programming of micro computers in some ways followed the development of mainframe programming which started about 25 years ago, e.g., machine language programming, assemblers, higher language programming.

There is, however, another event not found in previous computer development. The ease of obtaining and understanding the workings of a micro computer, and the fact that a much larger segment of engineers and even non-engineers were prepared and willing to use this modern technology had an accelerating effect on its development and use and created an interesting social mix of "positive feedback".

The picture looks more gloomy if we look into the way in which M/M computers in the form of small business computers are being applied to small businesses. Some argue that, in spite of all euphoria about M/M systems, "an individual businessman, who works at a small company whose sales are between $0.5 and $5 million today, has no place to turn to get quick, competent and inexpensive advice about which data processing option--a small business system or an outside service--is better for him" [8].

The situation in developing countries may be even more complicated. Some of these complications in a rather limited area are well described in the paper by Elkins, Matthews and Pomeranz [9].

Managerial Consequences of M/M Computers

Managers are engaged in varied sets of activities. The application of M/M computers is undergoing modification and will continue to change the organization of these activities thus leading to major changes in business operation. The main effect of this impact is the expansion of managerial skills and abilities.

The main purpose of a deeper study in this respect could be to develop some criteria and guidelines for managers entering the field of M/M computers.

A prepared manager should act in anticipation of, and not in reaction to, the consequences of the M/M computers.

Managerial and business applications of M/M computers seem to be most promising. The fulfillment of these promises depends to a large extent on the overall cost trends of computer systems and at least the secondary impact of these trends. All this makes the estimation of performance and suitability of a computer system for a given task a complicated analysis with conflicting objectives. It is generally agreed that the most reliable trend is the decrease of hardware cost to, in some cases, a negligible level when compared with the total cost. This is about the only decreasing trend--all other components of the total cost of computer systems are increasing. This immediately provides a strong economic incentive to shift the cost of labor into the capital costs of hardware.

Consequently a trend of decreasing advantage of central computers in batch processing and remote job entry to central computers, and even in the conversational access to central computers can be expected because the cost of data input operation, staff and its accommodation and line costs (in Europe, not in the U.S.A.) are expected to grow.

On the other hand, local stand-alone M/M computers with dial-up access to central computers; local stand-alone M/M computers with several terminals accessing one file; and personal computers will show an increasing advantage because they eliminate the escalating components of the total cost of computer systems [10].

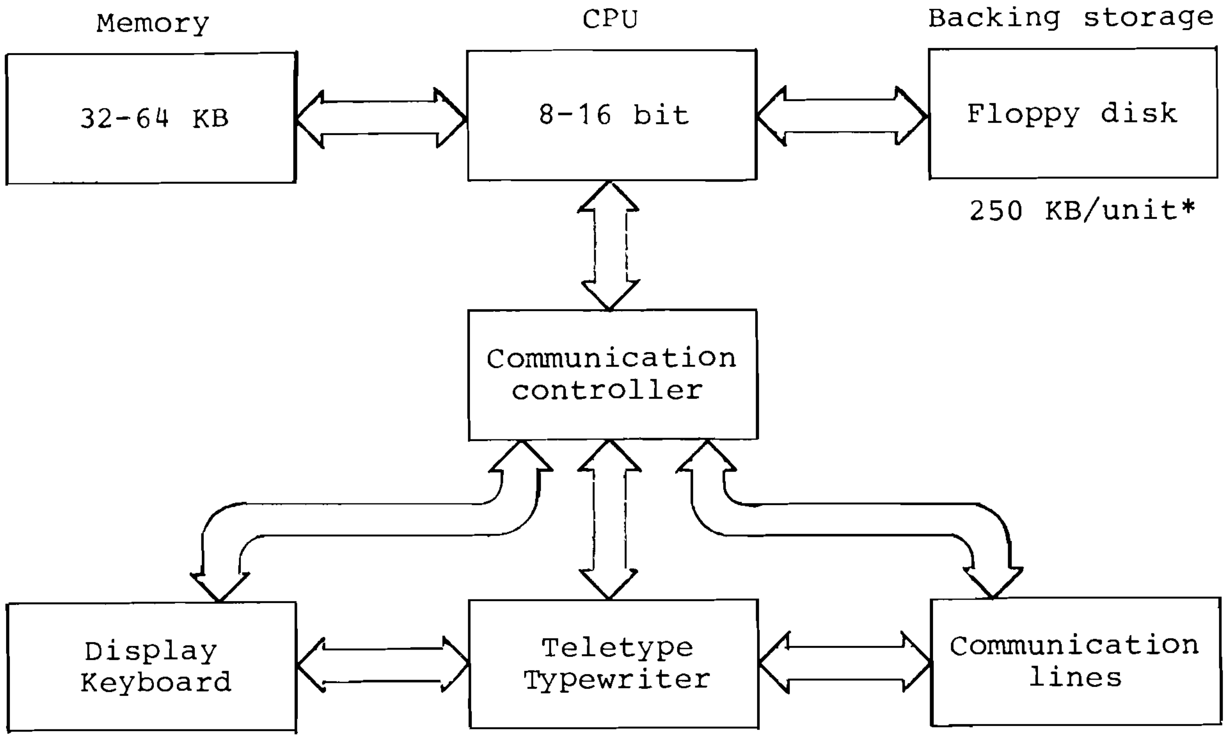
The small local M/M computers with appropriate software have a special appeal to many managers because to a big extent they eliminate the managers' feelings of "alienation". This feeling is evoked from the fact that his data was processed in a "foreign" central computer department over which he had almost no control and which had its own--and different--priorities.

The above-described trends led to the widespread use of business and/or office computers. Only a few years ago, the cost of a small business computer was in the range of $100,000 or more. Now, similar systems hardware usually costs less than $10,000. The software packages available from major manufacturers allow today's small business systems to perform as a kind of electronic filing system with basic clerical and secretarial facilities.

A typical small business system (M/M computer-based) has the configuration illustrated in Figure 1.

In order to perform the functions mentioned in Figure 1 with minimum of computer specialists interference a small business system is equipped with software of the following structure:

- -- operating system, requiring not more than 8k bytes in main memory;
- -- data management module, with elementary data base facilities enabling access and manipulation of structured data in files;



* There are experiments to connect discs with megabyte capacities to a micro computer [11].

Figure 1. A Typical Small Business System (M/M Computer-based)

-- word processing module controlling text output with possibility of formatting;
-- dialogue processing module controlling and analyzing interactive dialogue of terminal user;
-- some kind of job control language allowing users to construct nested command files of system commands;
-- program development facilities with high-level languages and associated aids for linkage, tests, listing and documentation.
-- applications library of specific application modules, usually written by an OEM supplier,
-- applications programs which represent the end-user interface.

This software and the cheap hardware opened new applications that previously were economically prohibitive. Business applications include:

-- payroll
-- cost accounting
-- accounts receivable and payable
-- word processing
-- sales processing
-- sales analysis
-- mailing list maintenance
-- market survey tabulation.

This turned out to be economically effctive even for the company with a few tens of employees. With more exclusive software, M/M computers can perform:

-- work scheduling
-- bid estimates
-- financial planning and analysis
-- real-estate and loan evaluation
-- tax calculation
-- appointment calendars
-- stock market analysis
-- personnel records
-- trend analysis
etc.

With the advent of M/M computers several ways to get the needed software emerged. Some software is delivered by the hardware manufacturer. That has been the only way since the beginning of computer applications. Recently there are many small firms specializing in systems analysis and software production. Thus the obvious disadvantage to the user of not having the necessary software from hardware manufacturers can be, at least in part, eliminated. This option of course can diminish in part the price advantage of a M/M computer.

More skilled users of M/M systems are writing their own software. This tendency will prevail with the spread of personal computing. When going into more detail one can state that M/M computers are equipped with operating systems of similar structure, but much simpler than the mainframes, and they do not have all the facilities the bigger computers have. That is not always a disadvantage, it is sometimes even the reason for more efficient performance. Operating systems of big mainframes are tuned to the more complicated architecture (several levels of memory hierarchy, managing the flow of large volumes of data sets between these hierarchies, complicated access to peripheral equipment, etc.). The design of M/M computers being simpler, an operating system which takes less than 8KB of memory may perform satisfactorily for a given problem, not having of course the flexibility of the mainframe incorporated.

For applications in managerial systems the availability of an appropriate higher-level language like COBOL seems to be very important. Historically the M/M's were not intended for business systems; therefore, only in the last few years some compilers of COBOL have been available and one can record the design of some COBOL compilers even for micro computers.

The above features of M/M computers, together with some to be mentioned later, have evoked an interesting discussion of mainframe vs. M/M computers [12]. It is impossible to give a general and yet a simple answer to this question, because not only technical but complicated economic questions are in play (vested interest, price of transition to new systems, etc.). It is safe to say that mainframe computers will stay with us, but that their share of the market may change and will shift more to the replacement applications.

One cannot resist mentioning one radical change brought about by the cheap computing power of M/M computers. In early systems the CPU was very expensive (and fast), therefore the economy dictated the maximum use of it, which led to internal time-sharing and multi-programming with the due penalty of complicated control. Now the situation is reversed. CPU in microsystems is almost free--who would care to share this resource? Therefore this in an invitation to long-awaited multi-processor systems with many important features on which to capitalize, such as:

-- high speed of operation
-- high reliability (through graceful degradation)
-- short response time, etc.

There are many questions to be resolved, especially in paralleling automatically complicated problems. Some problems can be paralleled easily when sub-tasks are not interdependent, for example in airline reservation systems. The big pay-off of this potential research will fuel many activities in this field.

M/M computers have much promise in many areas where real time operations are involved, for example in banking, airline reservations, and marketing. Micro computers made it possible to create cheap terminals which are leading to terminal networks driven by mini computers. In banking, systems with 6000 terminals are under development. These systems may replace the traditional batch processing systems and pave the way to wider implementation of discussed-and-awaited electronic funds transfer system (EFTS). The use of EFTS will create some legal and even social problems.

Many successful CAD or CAM systems use mini computers equipped with some graphic devices. This has a big potential which has not yet been widely used for increasing the efficiency of highly qualified professionals.

M/M computers provide the manager with complex information on production processes, making possible more optional designs.

The Organizational Impact of M/M Computers

For at least two decades computers have been influencing the organizational design and the way organizations are managed. This impact is realized in management information and control systems. Many goals originally set for these systems obviously have not yet been achieved.

This problem is worth a separate study [13], but for the purpose of this paper only a few selected facts are mentioned. In this respect perhaps the most discussed impact of computers is their role in the age-old problem of centralization vs.

decentralization in an organization. The self-evident advantage of centralized organization was limited by the information processing ability of the center, thus creating the hierarchical structure with its advantages and drawbacks. The essence of this was well described in [14 and 15].

The early forecasts [16] predicted that under the impact of computers large industrial organizations would reverse the trend toward decentralization and would "recentralize" under the benefits of processing capability of this new technology. This trend has not always been confirmed. Organizational structure has not been found to depend strongly on the computer, which can facilitate either centralized or decentralized structures. Some researchers argue that computers tend to reinforce centralization under stable conditions and decentralization under dynamic conditions. This question is more complex, at least as much as is the management of an organization. In many very decentralized organizations some activity remains centralized. Many centrally prepared plans have been implemented in decentralized structures. So it is not safe to give definite simple statements in this area.

M/M computers have reduced the economies-of-scale advantages of large computers and are leading to the wider use of distributed processing. Similar systems permit a cost-efficient match between an individual user's needs and the computer capacity. Individual departments have their own M/M system for performing local work.

Larger computational tasks can be passed to large computers or solved by dividing the task among several computers in the network.

Nevertheless the ability of M/M computers or computer systems to respond more effectively and efficiently to the requirements of the organizational structure creates an additional driving force for the move to distributed processing. This special feature of M/M systems can be stated [17] in the following way--these systems:

- -- allow assignment of the costs of data processing operations at the lowest level of the organizational structure;
- -- allow maintenance of a uniform corporate system in a geographically dispersed environment;
- -- permit efficient mechanization of many clerical activities, freeing more time for projects and tasks;
- -- permit more easily the use of new technological advances and growth of the system.

The above-mentioned question is related to the technically very interesting question of distributed data bases. Centralized data bases were a natural consequence of mainframe development and its economic environment. With distributed data bases many of the above mentioned features are well combined with distributed processing, resulting in:

-- higher speed of access to the data;
-- processing closer to the data and corresponding to the organization structure;
-- better reliability (graceful degradation);
-- reduced communication.

This trend will get a new impetus with the diffusion of personal computing.

All these new features of a computer technology in general and M/M systems in particular will have a radical effect on the interactions of the data processing systems structure and the organizational design. The technology of M/M computers, the data bases, word processing and communications can be integrated into corporate structure of any organization. It manifests a greater adaptability when compared with the effect on an organization of a centralized batch-processing system.

The Future of M/M Computers

It is difficult to predict the future of such a rapidly expanding development as the M/M computers. The global mini computer market is estimated to be $6.5 billion in 1981.

An increasing part of hardware costs in any modern computer system is represented by the cost of peripherals. The growth of M/M computer application caused of course new opportunities for peripheral manufacturers. The result of a market study made by Frost & Sullivan (N.Y.C.) ended in the prediction that total cumulative miniperipheral shipments over the years 1977-86 will add up to $37 billion [18].

In most of the IIASA member organization countries the annual growth of mini computer installations for the period 1975-80 is around 50% (U.S., Netherlands), the highest being in Italy (133%) and the lowest in Sweden (30%) [19].

The technological development of M/M computers will continue in the foreseeable future at a pace similar to recent years, following the development of large computers [20]. Mini computers are step-by-step enhancing their performance and acquiring the features of large computers. This is valid for pipe-lining of operations, virtual addressing, use of cache memories and more sophisticated operational systems, etc. This will, in the very near future, lead in small business systems to a more interactive data processsing style called transaction processing.

Micro computers in their turn are following several years behind the development of mini computers, but opening new specific applications. New features are found in the latest 16-bit micro processors announced by leading manufacturers (INTEL-8086, ZILOG-8000, Motorola-6809, etc.). Together with cheaper peripherals and new semiconductor memories the price/ performance ratio is improving enormously and will continue to do so. Some manufacturers are not making a secret of the fact that in 1980 a true 16-bit micro processor (a few years ago a mini computer CPU) will be produced on a single chip.

Conclusions

The fast growing area of M/M computers application created the need for over-all studies which are being made in international organizations, scientific journals, market research firms, etc. Some of the studies are mentioned in the attached list of literature [22,23,24 and 25] where we list papers from the past two years only. But there still remains a need for new and coordinative work, on which IIASA should be engaged. The purpose of this paper has been to provide the background against which a decision can be taken.

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IMPACTS OF SMALL-SCALE COMPUTER TECHNOLOGY ON MANAGERIAL TASKS

Workshop group report by

M.A.H. Dempster, G. Fick, R.D. Hackathorn
and N. Suzuki

Introduction

Rapid developments are occurring in the field of computer technology. In particular, the emergence of small-scale computers (i.e., mini/micro computers) is causing many significant impacts on individuals, homes, schools, small businesses, large corporations, and government. The impacts of this technology on the nature of managerial tasks are very complex and indirect. Yet there is an important need to assess these impacts and to advise managers about appropriate usages of this new technology.

This paper attempts to establish a framework for analyzing the impacts of small-scale computer technology on managerial tasks and the related organizational aspects. These impacts cut deeply into the fabric of the organization so that many of the traditional theories of organizations may not be useful for understanding and reacting to these impacts. The conclusion of our discussion group is that more research is needed to identify the impacts of small-scale computer technology on managerial tasks, particularly in the area of the interface of the technology to the manager.

Information Technology versus Computer Technology

When discussing technological impacts, it is important to distinguish between information technology and computer technology. In the context of this paper, information technology refers to any mechanism for processing data and transforming that data into information that a manager can consume in his/her decision-making process. Information technology is highly dependent upon the individuals and organizations concerned.

Computer technology, on the other hand, refers to a subset of information technology that employs data processing equipment (i.e., computers). Computer technology is contrasted with manual forms of information technology which are labor intensive and where the capital investment in equipment is minimal or non-existent.

The area of computer technology can be further subdivided into large-scale computing (LSC) and small-scale computing (SSC). This distinction is useful since it highlights the mini/micro computer technology with the maxi/midi computer technology.

New Opportunities versus Old Constraints

A complication with the study of the impacts of SSC is that this technology is concurrently performing both of the following two actions:

1. Introducing new opportunities; and
2. Eliminating old constraints.

New opportunities are emerging for performing managerial tasks in completely new ways. Whether managers will decide to utilize SSC is a decision that individual managers are facing on a daily basis and a policy matter that organizations are increasingly having to decide. This situation is exactly the situation of balancing current actual uses with potential future uses. Given a particular managerial task, SSC may be a necessary condition, but there are many non-technology factors to consider in determining the sufficient conditions.

The elimination of old constraints is a more subtle situation. Many of the organizational structures and managerial policies existing today have evolved from many years of adapting to various constraints placed upon the organizations. Constraints of past information technology have influenced significantly the fundamental nature of organizations. The authors believe that the new forms of information technology will allow radically different organizational structures and managerial policies to diverge from current practices. Further, the variety of management practices that can coexist within the same organizational framework will greatly increase. The coupling of organizational structure can be loosened, and the tolerance for variance in decision-making processes can be increased. This new flexibility of designing organizations is the challenge that SSC technology has laid before us.

Causal Relationships

To explore the impacts of SSC technology on managerial tasks, a framework was first built. This framework is shown in Figure 1. On the left side of the figure are certain characteristics of information technology acting as the independent variables in a sequence of causal relationships. On the right side are certain

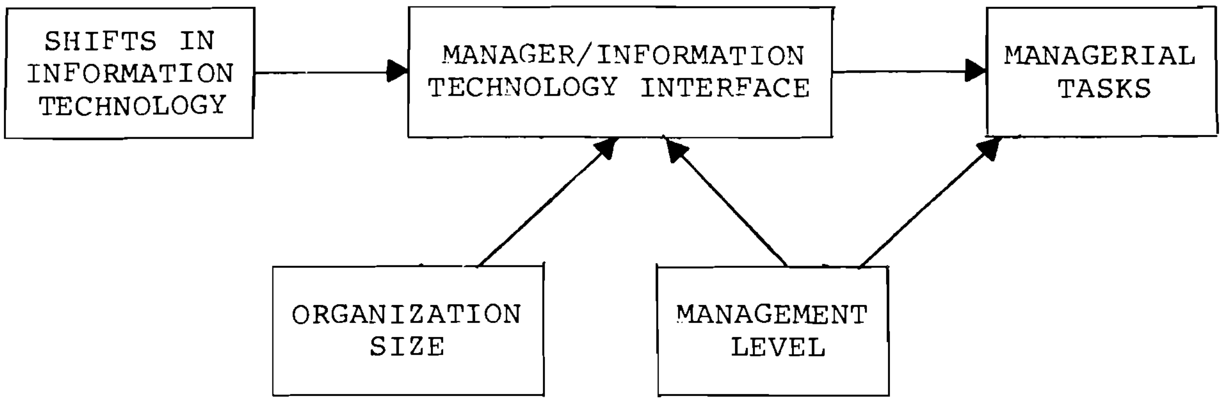

Figure 1. Causal Relationships of Impacts

characteristics of the managerial tasks acting as the dependent variables. An important contribution of this paper is to hypothesize that there exists an immediate variable between the information technology and managerial tasks. This immediate variable is called the "Manager/Information Technology Interface" or the M/IT interface.

The significance of the M/IT interface in the above causal relationship lies in the fundamental nature of how a manager interacts with the information technology. The impact of small-scale computing technology is that this interface is much more "personal", thus integrating better into the normal routine of the manager.

Figure 1 also shows two other variables acting as intervening variables to the M/IT interface and managerial tasks. The first intervening variable is organization size. Depending on the size (and hence complexity) of the organizational structure, the M/IT interface will react differently to the information technology. The second intervening variable is management level, which is defined in terms of Anthony's three-way categorization of operational control, managerial control, and strategic planning.

The next three sections will explain in more detail the three major variables in Figure 1 in the order: (1) information technology; (2) interface with the manager; and (3) managerial tasks.

Transitions in Information Technology

This section will focus on the nature of the information technology and, in particular, certain transitions that are occurring in the form of that technology. The argument is made that it is these transitions that are causing the significant changes in interfacing the technology to managers.

The application of computer technology has broadened over the past twenty years from singular applications (such as payroll) into almost every facet of an organization's operation. This transition from manual to computer-based information processing has mainly been one of applying large-scale centralized computing to mechanizing manual tasks. In the past, the alternative of applying small-scale computing has been uneconomic because of considerations such as hardware costs and limited storage facilities.

As stated previously, the three forms of information technology can be characterized as:

1. Manual procedures;
2. Large-scale computing (LSC); and
3. Small-scale computing (SSC).

The logical functions performed by the technology is similar in all three forms. The above distinction is based upon the nature of the mechanisms, rather than differences in the processing itself.

Large-scale computing can be characterized by a centralized computer system utilized either for batch processing or interactive processing via time-sharing techniques. Small-scale computing is characterized by minicomputer or microcomputer systems designed to satisfy the local information processing needs of a manager. The differences in defining the terms of LSC and SSC are based on the extent to which a manager's information processing needs are satisfied locally versus remotely. Further, the term "manager" can refer to an individual or a group of persons working closely on the same task.

As shown in Figure 2, the main transition in the form of information technology has been the shift from manual procedures to large-scale computing. The data processing industry to date can be adequately described in terms of the implications of this transition.

It is more important, however, to focus on the two other transitions shown in Figure 2, which are: (1) the shift from large-scale computing to small-scale computing; and (2) the shift from manual procedures to small-scale computing.

Some of the difficulty in understanding the impact of SSC on organizations stems from not recognizing that there are two concurrent transitions in technological forms. The first transition (labelled "A") is the transition from LSC to SSC. This transition is the one normally implied when discussing topics such as distributed computing and distributed databases. The underlying implication is that the degree of centralization of the processing activities is being lessened by decentralizing some activities to local SSC nodes.

The second transition (labelled "B") is often overlooked. It is the shift from manual procedures to SSC. For various

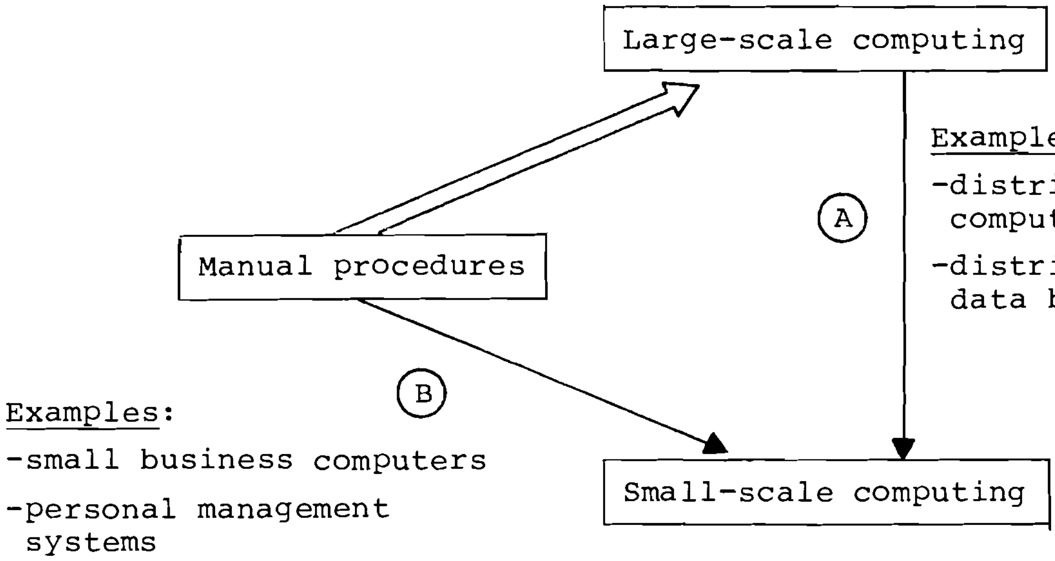

Figure 2. Transitions in Information Technology

reasons, many manual procedures have not been shifted to LSC. Economic considerations are a major reason. Examples of this transition are the booming area of small business computers and the personal management systems owned secretly by many managers in large corporations.

Manager/Information Technology Interface

This section focuses on the interface between the manager and the particular form of information technology that he/she utilizes in performing their tasks. The section will consider a series of characteristics concerning the M/IT interface in terms of the impacts that SSC technology is having.

Personalization. The first characteristic of the M/IT interface is the degree to which a manager can personalize or customize the technology to fit the managerial task. SSC is having a major impact through increasing personalization. In fact, many refer to small-scale computing as "personal computing", thereby implying that microcomputers are being used primarily on a personal level.

Friendliness. Another characteristic of the interface is the degree to which the manager perceives that the technology is "friendly". This characteristic is an emotional perception by the manager that can have important side-effects on adoption patterns, etc.

Predictability. The degree to which a manager can predict the outcome of using a certain information technology is related to the extent to which that manager utilizes the technology. To state this assertion another way, the average length of time to obtain a useful response is not as important to a manager as the variance in that length. If a manager can predict with a high certainty when and how the technology will supply useful information, then the manager can plan to incorporate that information in a larger activity. Uncertainty prohibits the manager from planning.

Self-Control. The degree to which the technology is under the manager's direct control is positively related to the utilization of that technology. An analogy to the telephone may be useful. Sharing a telephone among managers will cause more inconvenience than purchasing telephones for each manager.

Confidentiality. It has been stated by many authors that information is power. Therefore, the degree to which a manager must share his/her information negatively affects the manager's power. The information technology should allow variable amounts of confidentiality for the data used by a manager.

Involvement. If a manager is directly involved with using the technology, the manager can more effectively use that technology. Since LSC technology has often been centralized into a separate organizational unit, SSC technology has once again allowed the manager to be involved with the technology.

Adaptability. The technology needs to adapt to the changing environment faced by the manager. Since the manager is responsible for all phases of the information processing activity, changes to the information system require less coordination among individuals. Hence, the information requirements can be translated more easily into usable software programs.

Managerial Tasks

The characteristics of the managerial tasks were elaborated by another seminar discussion group. Managerial tasks are affected by SSC technology in terms of increased variety in managerial activities, more loosely coupled systems, and a decentralization in information processing activities.

Conclusions

Based on an elaboration of the framework presented in this paper, it should be possible to identify bottlenecks in the future dissemination of SSC technology into the management functions in organizations. Further research is needed to explore the impacts of this new technology and, thus, more effectively utilize it to increase productivity of organizations.

THE EXPECTED EFFECT ON MINI/MICRO COMPUTERS ON ORGANIZATION

Workshop group report by

G. Dobrov, A.S. Douglas, H. Eto and G. Hofstede

It is a common experience that new computer tools have been used as an excuse for the introduction of organizational changes which were desired by management anyway and which were not dictated by the nature of the tool or its efficient use. However, it is true that, because of the economies of size, expressed roughly by Grosch's Law, mainframe computers have tended to fit more readily into a centralized structure than a decentralized one. This situation has been steadily eroded, since the economies of size can only be realized if substantial amounts of data are transmitted from remote sites and if a complicated operating system is constructed to handle the distribution of computer resources to a multiplicity of tasks on a dynamic basis. Both transmission costs and the substantial overhead incurred by these operating systems have detracted from the economies of size.

The new technology being studied has reduced the cost of computing, and has so far been deployed to provide cheaper small systems for local use rather than in mainframes, partly because of machinery considerations and partly because of the phase of mainframe development by the major manufacturers during which the technology has been introduced. It is considered probable that, during the period under review, although significant changes in mainframes may take place, telecommunications costs will reduce slowly, so that economies of size will be less easily realizable than before. The tendency will therefore be toward local operation on M/M systems with cross-connections established as seems most effective and economic to the units concerned. There will be much less economic pressure towards the centralization of computer facilities, although some central control of the cross-connection, between units within an organization will be essential to ensure effective internal communications.

We foresee several effects flowing from this:

1. It will be easier to introduce computing into an organization, since machinery is cheaper and, within limits, local decisions can be taken to acquire them--indeed the smaller systems are already more in the nature of office equipment than a major investment. Moreover the introduction can be proceeded by smaller steps.
2. There will be a potential for greater variety in cross-connecting, loosely coupled sub-systems which are supported on local computers. This can lead to a lesser overload on communication channels at all levels. The resulting system is easier to repair and has greater flexibility than a "central" system. However, we recognize that this can only be ensured if suitable standards and protocols, laid down centrally, are adhered to. Thus the role of central computer management will change from the position of large scale "service centers" to that of coordinating and orchestrating a variety of machinery within a "network"--which may well include the use of external service facilities as well as machines operated internally. It is inevitable that existing service centers will, to some extent, resist these changes, and careful planning will be needed, supported by top management.
3. As computer power becomes cheaper, some part of this advantage is likely to be used to make machines easier to use. There will continue to be a demand on high-level software experts to achieve this, nevertheless the proportion of these experts to the general user population will tend to fall. There will be a greater need for training at this level of the general user, who will need to be less of a computer specialist than now. Existing users will need to be retrained and updated to reduce their resistance to the inevitable changes.
4. The wider spread of computing at the clerical level, which we see taking place initially as a result of word processing equipment replacing typewriters, will tend to affect the managerial control cycle, by spreading out the passing of information between managerial centers. This speed up will help to improve the response of organization to change, and may well affect the span of control of individual managers, although the technology will not require this.
5. There will inevitably be a change in the power and status dictated to existing jobs within an organization as a result of the changes referred to above. Insofar as the possession of information and the right to control access to it represents power, the introduction of this processing power at the level of data collection implies more power spaced through the organization and gives the possibility for wider participation in the

affairs of the organization. The power and status changes for existing expert groups has already been referred to, and some new expert areas identified in 2 above. Clearly the disturbances involved require careful managerial attention if the most is to be made of the opportunities offered by the new technology.

SOCIAL IMPACTS OF SMALL COMPUTER SYSTEMS

Workshop group report by

E. Braun, A. Csakany, A. Douglas, H. Maier
and H. Rosenbrock

Employment and the Nature of Work

There is little doubt that small computer systems can be used to automate many production processes and to increase the efficiency of many administrative processes. If this can be done economically, as undoubtedly it can, then the net result of using small computer systems must be increased economic efficiency. In the world of pure economic theory, increased efficiency is a pure blessing which should lead to a greater satisfaction of human needs. In the impure world of reality, many people fear that the increased use of labor-saving technologies will, on balance, lead to endemic problems of unemployment.

The cheapness of the logic gate and of a small system is such that in many cases the factor substitution of computers for human operators will be justified on economic grounds. The main likely areas of substitution are in simple office tasks (word processors), printing, machine tools, warehousing, assembly, material handling, etc. Undoubtedly the production of labor-saving machinery itself will require labor and many new products will come on the market, giving new employment opportunities. There is a real possibility, however, that the balance between removal and creation of job opportunities will be unfavorable not only in the short term, but also in the long term.

The main worry of many people is that it will be particularly difficult to find employment for the uneducated and unskilled, as such workers are most readily replaced by computer controlled systems.

It would appear that at present the dangers of technological unemployment are not apparent in the socialist countries, but whether they will remain permanently immune is an open question.

In both Eastern and Western countries, the total amount of economic disruption, and possibly unemployment, caused by small computers will depend on many factors. Crucial amongst these are the total management of the economy, the state of world trade, the smoothness of uptake of the new technologies, and many more. We have insufficient knowledge of many of the factors involved in the smooth introduction of small computers or computer based machine tools, including robots. We also have insufficient empirical knowledge of the full consequences of the introduction of small computers or automated machinery at plant level. Several research groups are carrying out investigations into these matters and some international cooperation in such research would be highly profitable. Among others, the Technology Policy Unit of the University of Aston in Birmingham is attempting to analyze the factors which enhance or retard the introduction of electronic automation, including robots, in manufacturing industry. The same study also investigates the results of the introduction of automation in human, economic, managerial and other terms.

A vitally important topic, though one on which we as a group have very little information at present, is the question of the impact of small computers on developing countries. It is possible that they will have the effect of greatly enhancing managerial efficiency and thereby give impetus for economic growth. On the other hand, it is possible that the developing countries might lose what advantage they have from cheap labor, as manufacture in advanced countries becomes less labor-intensive.

On balance, we do not think that over the next ten years there will be a considerable change in the nature of work or in attitudes to work. There may be reductions in the working week, the working year or the working life, but basically people will continue to seek employment. In all industrial societies employment not only provides people with a livelihood, but also with social intercourse and some external validation of their activities. It is very unlikely that over the next ten years or so any social forms will have developed which could replace work as a means of directing and validating people's efforts and as a means of providing companionship and a framework for social relations. Even if a "social wage" were paid to everyone, we do not think that attitudes to work would change very markedly.

Education and Training

There is no doubt that small computer systems will require changes in educational and training provisions. It will become increasingly inappropriate to train people only once in a lifetime because rapid technological changes require constant adaptation of skills. Education will have to provide flexibility of mind and training will have to cater for flexibility of skills. Even definitions of skills will have to become more flexible, with as few boundaries as possible. All arrangements for fitting people into jobs and providing jobs fit for people will have to become flexible and will require a lot of thought. Even now we observe a situation where considerable unemployment runs side by side with severe shortage of skilled workers.

Small computers themselves may be used as aids in training and possibly in education, but no real replacement of teachers is foreseen.

Much argument centers on the question of gradual de-skilling of jobs by machines. Certainly many past skills have disappeared and division of labor has led to fractional jobs. It may be argued that the small computer will take over many of the most routine tasks and that the programming, supervision and control functions associated with it will lead to new skilled jobs. It may be that the number of such jobs will not match those skilled jobs replaced by computer controlled machines and that the process of de-skilling will continue. This is a matter on which active policies ought to be pursued.

Privacy and Security

Problems of privacy and security may become more severe as the scope for widely scattered and widely accessible data files increases. It will be necessary to make sure that information on individuals, possibly erroneous or slanderous, cannot be used against them. Ways and means of achieving this will have to be decided by different societies in their own ways, but potential for abuse certainly exists.

Mobility and Transport

The question of whether the increased use of computers and of communication links will decrease demand for travel to work and in conjunction with work has been discussed. In particular, it has been suggested that the office will become somewhat obsolete and will be replaced by the office in the home. Several conflicting forces may be discerned. On the one hand the technology to link widely separated workers by effective communication links does exist, but on the other hand the need for personal contacts is a strong force bringing people together. As the cost of large office blocks and the consequent transport becomes greater, so the possibilities of decentralized offices will become more attractive. It is doubtful, however, whether this will go as far as the office in the home on a large scale. One effect the possibility may have is an increase in the number of women seeking employment, especially women with young children. It will be necessary to devise methods of supervision and remuneration of such home-workers.

Service and Service Industries

An important effect of small computers will occur in services. With word-processors and various efficient information systems, services can become more efficient and thereby increased consumption of such services will be facilitated. The advantages of consumption of services, rather than increased consumption of goods, can be considerable; mostly in terms of conservation of energy and other natural resources. It is possible that efficient services will create insatiable demands and thus alleviate problems of technological unemployment in the manufacture of goods. One of the new services will be the provision of information in the home, others will be educational, recreational, administrative, financial, etc.

Some services traditionally provided externally will become internal by the use of new capital equipment. An example is the use of in-house printing instead of external printing. Similar examples may occur in the home, with home entertainment and information equipment partially replacing some external services. The chances are that the total use of services will thereby increase rather than decrease.

A RESEARCH PROPOSAL

A compilation of the workshop recommendations
by

G. Fick and R. Tomlinson

Background

It is a matter of general knowledge that the revolution in the technology of semiconductor devices has caused a spectacular development in the computer field. It has produced new patterns in large scale computer systems and a dramatic change in small-scale computer systems. The rate of technical development is still incredibly rapid, and it is difficult to see all the possible fields of application so far. Many assessment studies have been carried out in recent years. Some trends are already clear however, and these show that there are great potential impacts on society. Again, many studies have been carried out on the impact of computers and automation, some of which include mini/micro computers and some are devoted to them. Relatively little attention has been paid to the direct interface between this new computer technology and what people actually do, even less to the possible organizational consequences. These are important issues to our society, directly relating to the impact of technology. Their study involves an interdisciplinary approach to complex systems. They are therefore particularly appropriate to the Management and Technology Area at IIASA.

Benefits and for Whom

In the first place, this would be background research, charting the field and identifying issues. The primary interest groups would be those governmental bodies designing public policies in the field, industries engaged in hardware development, software producers, management teachers and organizational designers. Clearly the national policies of research and procurement support, together with manufacturing and labor policy could benefit from the exploratory study. In the longer term, if the study leads to a wider investigation relating to management information systems, the potential client range is greatly broadened.

Objectives

The primary objective must be to identify the options for and consequences to management--these are the first order effects in organizations. But the second order effects may in practice turn out to be of greater importance in the long term. Consequently, the study cannot ignore the consequences on unemployment, education, privacy, mobility, etc., and needs to draw on specialized research being undertaken elsewhere in this field. It must certainly build on the work of technology assessment to ensure that it rests on a sound foundation, so far as technological developments are concerned. This emphasizes the need for IIASA research to be undertaken on a collaborative basis.

Program of Work

At the workshop, a number of research proposals were identified as is indicated in Table 1. After discussion, it has been decided to concentrate on two main topics:

1. The manager/information technology interface;
2. Software development.

The first topic will start with the preparation of a scientific paper on framework analytical tools. The work will then proceed by case study and, of course, literature search. In the first place, the case study methodology will be developed in two different countries, so as to establish a means whereby consistent information can be provided from many sources for comparative purposes. (Traditional questionnaires are likely to be inadequate.) After discussion, a wider range of case studies would. The synthesis should be complete in about 18 months.

The second topic would be concerned with software developments. The restrictions that software will place on the extensive use of small scale computer systems, are as yet inadequately understood. The one sure thing is that they will be different from the restrictions imposed by traditional systems.

A tentative schedule of the proposed activities is indicated in Table 2.

Project Resources

IIASA must take a central place in project planning and analysis, but the work as a whole can only be done on a collaborative basis. This collaboration will take a number of forms.

Table 1. Summary of Proposed IIASA Tasks

	Group 1	Group 2	Group 3	Group 4	*
Man-computer interface/scientific paper	x	x			1
Impact on information systems, decision support systems	x	x			1
Impact of standards on the development in general	x				2
Applications to IIASA programs and tasks	x				
Reports	x				1
Proceedings	x				1
Handbook	x				
State-of-the-art report	x				2
Case-study		x	x		1
Field survey		x			1
Workshop on interface		x			1
Workshop on packaged software		x			1
Literature study		x	x		1
Criteria for appropriateness of SSCS			x		2
Guidelines for organizational design			x		2
Guidelines for training			x	x	2
Identification and coordination of ongoing research				x	
IIASA Conference to launch project	x				
IIASA Conference in the middle of IIASA research				x	
IIASA Conference to conclude IIASA research			x		1

* Last column
1 = covered fully by proposed activities
2 = covered in part by proposed activities
empty = not covered

Table 2. Tentative Schedule of Activities

Activities	1979 Winter	1979 Spring	1979 Summer	1979 Autumn	1979 Winter	1980 Winter	1980 Spring	1980 Summer	1980 Autumn	1980 Winter
1. Specialist workshop to explore the field										
2. <u>Manager/information technology interface</u>										
2.1 Scientific paper on framework, analytical tools (working group)	X									
2.2 Presentation of paper, Workshop to discuss and evaluate (at IFIP Conference in Vienna)			X							
2.3 Case studies in NMO's (e.g. Philadelphia, Bratislava)		X								
2.4 Literature survey		X	X	X	X					
2.5 Summarize case studies and literature, establish methodology for 2.6 workshop/working group			X	X						
2.6 Field studies in NMO's				X	X					
2.7 Synthesis						X				
3. <u>Software developments</u>										
3.1 Literature survey		X	X	X						
3.2 Technology assessment and report		X	X	X						
3.3 Workshop (possibly sponsored by Wharton School)				X	X					
3.4 Synthesis						X	X			
4. <u>Limitations</u>							X			
5. <u>Report</u>								X	X	
6. <u>Conference</u>									X	X

In the first place, the overall framework and the analytical tools to be used will be devolved in collaboration with a broad group of scientists. The technological and societal limitations will need to be explored with the specialists concerned, possibly in task force meetings. The case studies will need to be done with support from IIASA's National Member Organizations and specialist groups.

Project Duration

It is estimated that the project should take from 1 1/2 to 2 years.

APPENDIX: List of Participants

Seminar on Management and Organizational Implications of Computer Development

September 26-28, 1978

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