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INFORMATION NETWORKS USING MINICOMPUTERS: DESIGN GUIDELINES*

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ABSTRACT

We place in focus the need for systems architects and designers to appreciate that their hardware and software is always part of a larger Information System to which it should be morphologically related in concept and implementation. Information Systems for most, large, real-world organisations are intrinsically dispersed, and require a “distributed-intelligence” approach.

In developing countries where the environmental economics may not now permit extensive use of real-time on-line networks, the <u>Information Network</u> approach enables us to approach the systems design problem in the same systematic manner - whether or not real-time communications facilities exist. The same systems architecture applies whatever the means we use to link the components of the network: telegrams, cassettes by mail, tape reels by courier, telex or R-T circuits.

By defining and. approaching the design problem as one of building Information Networks, it allows us to transcend the conventional dichotomy between single-station or batch Data Processing and multi-station, real-time Systems. This enables us to lay down a set of guidelines useful for The designer, user, and policy-maker.

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0. **Introduction**

Because of the rapid developments abroad in electronics and computer technology, and especially in computer-communications, the professional community has been much exercised over the new possibilities opened up by having “networks” of computers. Recent evaluations of .**ARPANET** have proven its complete economic infeasibility even in the USA as a general purpose ‘network’ computer utility. What then <u>is</u> possible? It is the purpose of this paper to provide a systematic framework in which these possibilities can be explored.

We wish particularly to direct attention to the fact that most important informations applications or information systems have a network character already, and to the need to design system architecture to correspond to (that is, be isomorphic to) the shape of the information system which best serves the user organisation.

1. **Information Systems**

A system that transmits, stores, processes and distributes messages - entities employed for communication - is called an Information System. The word system is here used as a synonym for “**a collection of objects which are used in a pre-defined. manner**”. Information systems include people who transmit and receive the messages, the hardware equipment which store and process the messages and the communication medium which carries the message.

The terms **Data processing and Data processing systems** are quite popular and most often Information Systems are mistaken for the former. It should be emphasised that Data processing is a subsystem of any Information system and the people involved form a vital part of the Information System.

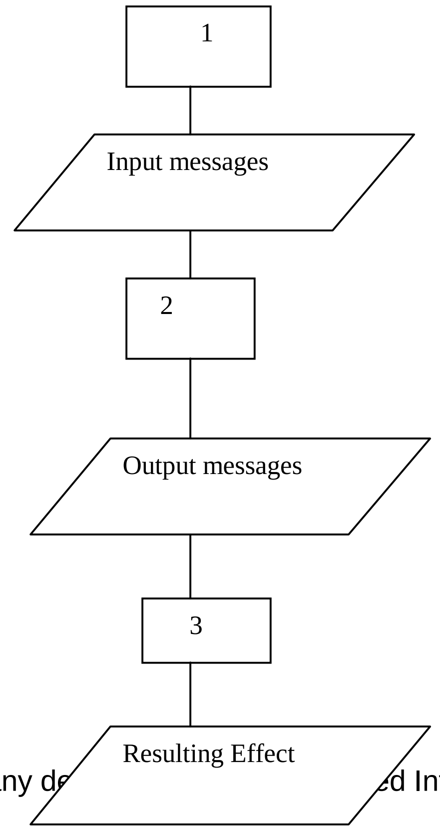


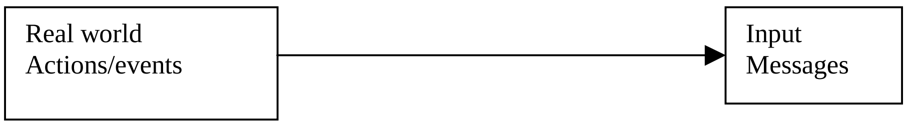
Fig 1. Information Systems

Hence, any d ... d Information system must include the following criteria.

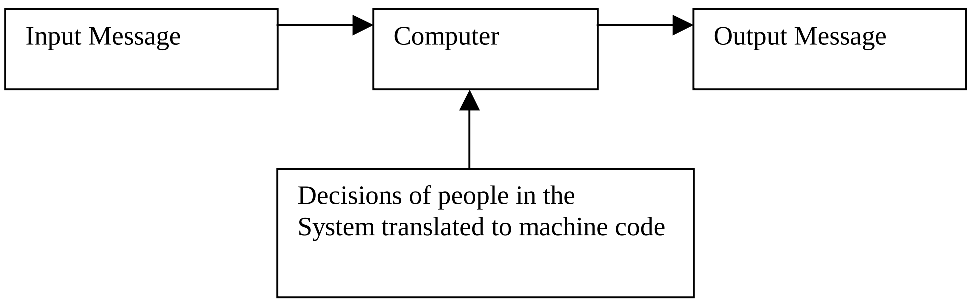
1. Viable and efficient methods of conversion of human action and judgements to formalise input messages for handling by the hardware.

2. Efficient and <u>robust</u> (fail-soft) computer/communication systems to store and process messages to transform input messages to output messages.

3. Development of personnel to perform necessary processing of messages based on their understanding of the messages in the light of a context outside these messages and the explicit instructions on how they are to be processed.



<u>Problem 1</u>



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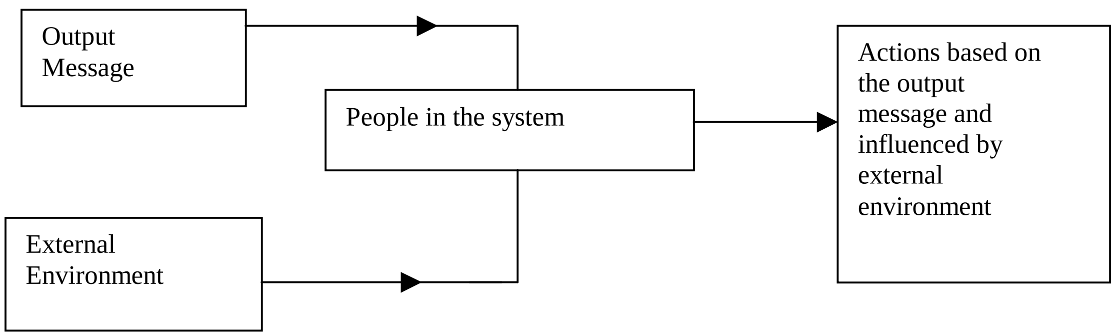


<u>Problem 3</u>

Fig. 2 Three aspects of Information System

2. Priority Information Systems

Considerable attention has been given in India to identifying priorities in the use of informatics technology in the developing countries. Much of the activity of the Department of Electronics is oriented to this end. Studies of past computer use in India have commented upon the fact that many of the large industries and key sectors of the economy are still bare of effective computer equipment. On the other hand much of the time of existing hardware is spent on historical accounting or in compiling statistics.

This is not the forum to explore such a policy issue, but we take it that there is a consensus that key sectors of the economy must be made more efficient through full use of informations technology. These sectors include Mining (Coal and Metals), Agriculture (logistics of agricultural inputs and. of commercial and food crops), Water management, Forestry, Steel, Major engineering industries, Transportation (river, rail, road, sea and air), Banking and Regional and urban Administration.

What are the characteristics that are common to these sectors?

a. They are all large scale public systems involving a large number of offices and personnel dispersed across a substantial area and often around the country.

b. The basic transactions involved in these sectors as well as the controlling and monitoring organisations are geographically dispersed..

c. The speed with which the localized transactions in such systems affect ‘global’ state-variables are slow compared to those for which on-line options are required. Updating of global data bases is less frequent than updating local data bases.

d. Since they are geographically dispersed, the individual subsystems need to be able to function quasi-independently in terms of the information available to them at any given time.

3. Information Networks

Just like a computer network, an Information Network is a number of information sources connected by information channels. Information sources at each node may include computers and the Information channels may be anything from high speed communication channel to movement by poet of cassette tapes with predefined formats. The characteristics of information networks are:

1. Information networks are usually hierarchical since they very closely reflect the real world system of which they form the object system.

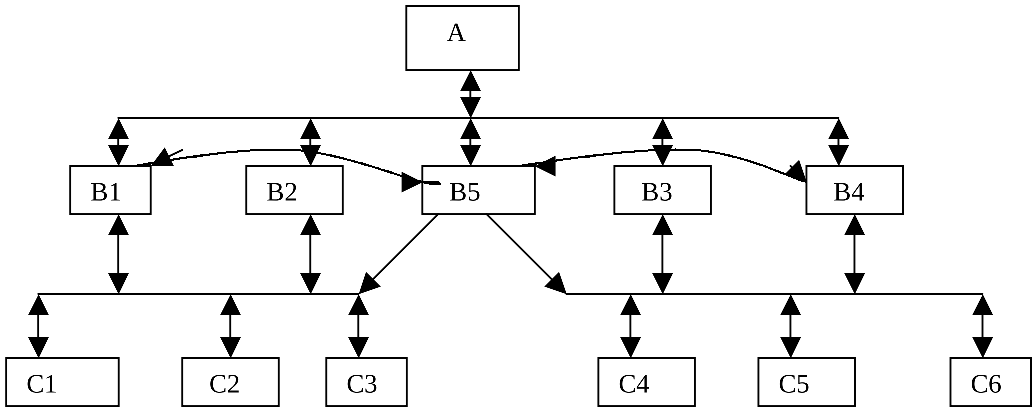
2. Updating of data bases become less an~ less urgent as the level of hierarchy increases.

3. There is an aggregation of information from level to level.

4, The amount of global information (information exchanged on the network) is much less than the local information (information generated and. used at a single node).

5. Local decisions and actions are made on the latest local information available. Hence usefulness of information at action levels decreases very steeply with time elapsed.

6. The need for instant communication among nodes does not usually exist. However, information has to reach the destination within predefined periods for it to be useful globally.



A : Headquarters
B1-B4 : Plants
R5 : Marketing divisions
C1- C6 : Distribution Centres.

Fig.3 *'Network' character of a typical priority Information System*

4. Information Networks and Minicomputers

An Information network implies decentralised decision-making and distributed information. In the operation of any large, geographically dispersed system, it is very often seen that decisions have to be made, and actions taken locally, based on the information available. In the absence of such information, decisions are either postponed or made injudiciously. Decentralisation of information-processing and information storage provides an overall perspective for each of the nodes since a certain amount of global information can be held there too, and so even local decisions tend to be better. Hence, there is the need for information technology at each node. This needs only to be large enough to support local files and transactions. What such networks need at each node are low cost, flexible and fail-soft computing systems. The advantages of using minicomputers at each node in these information networks are:

1. Minicomputers have a better performance - cost ratio than medium-sized computer systems for unbalanced loads.

2. For dedicated transaction-oriented applications, they are extremely efficient since they are micro-programmeable.

3. They are modular and hence provide flexibility and interchangeability.

4. Maintenance of software and hardware is relatively simple.

5. Since the computational load at each node is not expected to be high they provide a better utilisation factor than medium sized computer systems.

6. Expansion of any node is possible by adding one or more units since they are modular.

7. Users can build their own system to serve their particular application unlike larger machines where building an operating system is a very expensive job which can only be mortised over many and must therefore be general purpose (i.e. less efficient).

8. Last, but not least, we have indigenous machines available.

The question might be asked why the nodes of different networks need their own minicomputers. Could they not take advantage of the existing computer facilities in their town? Could they not buy time from others, perhaps even hook up to a large regional computer on a time-sharing basis?

Firstly, not very much 'idle time' exists today, according to the recent ASCI study. Secondly, what exists is on IBM 1401 computers which are likely to be rapidly phased out. It would be doubly unfortunate if they are now deliberately replaced by systems which are seriously enough mismatched to the requirements of the purchasing organisations to lead *to* conditions of idle time.

In any case, the informatics-technology needs of the nodal units in our priority information networks are unlikely to be met by the idle time in conventional data processing equipment.

As the experienced d.p. professional knows, getting the data into the computer correctly is four-fifths of the problem. This is a far more straight forward task with minicomputer-range transaction-oriented systems which are in-house, whereby errors can be corrected and recycled easily. In addition, formats can be changed and debugged and, in general, flexibility in processing and in timing assured to the real users of the system. It may not be impossible, but it is certainly rare for organisations who are obliged to 'rent' time outside because they do not have an in-house computer to be flexible in their data processing. They have to choose simple, standard packages or routines and stick to them on a fixed time schedule. Meanwhile the managers of such organisations find themselves building and acting on informal or 'desk drawer' information, rather than on what the formal computer-based information system provides them.

We must first accept that The purpose of putting together computer systems is to provide an effective service to the users of information systems, arid not to convenience a particular source of computer hardware, whether Eastern or Western by confining the information systems to suit this hardware. Next we must understand that information systems will develop new needs and linkages as the organizations/services which they support undergo development in size and sophistication. Only by giving each cell or node in such organisations an independent modular informatics facility can we assure that growth and flexibility in development of. the information system matches the organisation's needs. To use a biological analogy: the nervous system of humans and higher animals is highly decentralised with much 'local processing' taking place. The processing capability in each subsystem have evolved to match the demands placed on that particular subsystem - fingers, eyes, tongue, etc.

5. **Design Specifications for Information Networks:**

More often than not, however, information system design has been abnormally influenced by the technology available. It has become quite a fashion these days to think in terms of Real Time systems with response times from a global data base of a few seconds. While this may be necessary in the case of certain competitive Airlines reservation systems, air defence and one or two other applications, it is certainly not the most urgent need as far as Logistics Systems are concerned. In these systems, rapid access to a local data base and reliable updating later of local and global files is the key requirement. On the other hand, systems which are real-time on a global basis lean very heavily on a fast and reliable communication support. While a lot of progress has been made by the P & T in India, various conditions such as climate, thefts, etc. do render the communication lines highly vulnerable to failure*.

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* Discussion at CSI Bombay Chapter Seminar on October 24-25, 1975: Destination-to-destination reliability could be as low as 50% but the P&T claims that trunkline efficiency of 98% is feasible.

The tendency among many computer network designs has been to assure or demand ideal conditions from the environment and to design the computer part of the network accordingly. This reduces the work to that of adopting text-book patterns where data communications, power supply, spares and other environmental factors are assumed favourable.

It is our contention that Information networks should be designed keeping in view the performance under a range of conditions from bad to worst. Appropriate design may lower its performance under 'ideal' conditions in exchange for being able to function at some useful level even under failures of hardware. The points to be considered in such a fail-soft design are:

a. Performance under failure of hardware

b. Simplicity of use and maintenance

c. Ease of further development

5.1 Inter-nodal communication

The factors to be considered in the selection of the communication medium are:

a. Frequency of queries or exchange of information.
b. Whether all the queries can be grouped together till a certain hour e.g. 6 p.m. and sent together to the destination.
c. Type of queries: Li simple access to a data base or access-and-update.

d. Whether there is a need for immediate updating of the information at the destination.

If the queries belong to the last two categories then a leased line would be essential. However for case b, a dial-up telex link or voice- grade line available during slack hours would be sufficient. If the queries and. updates can wait a day, which is usually the case in government departments, then it may be quite feasible to link the nodes by hand-carried or mailed magnetic tapes (cassettes or reels). This may appear somewhat unorthodox to computer communication specialists but then it is a simple yet powerful way to carry the information. In such a system the updates are performed at the source node immediately on the local information base. If the information that is to be updated is global, the update material is recorded in a predefined format on a cassette and sent to the destination containing the global file.

It should be emphasised that the information network designer should envisage and plan for a skeletal services (batched update) via cassettes in case of communication outages and leased lines of 4-8 hours.

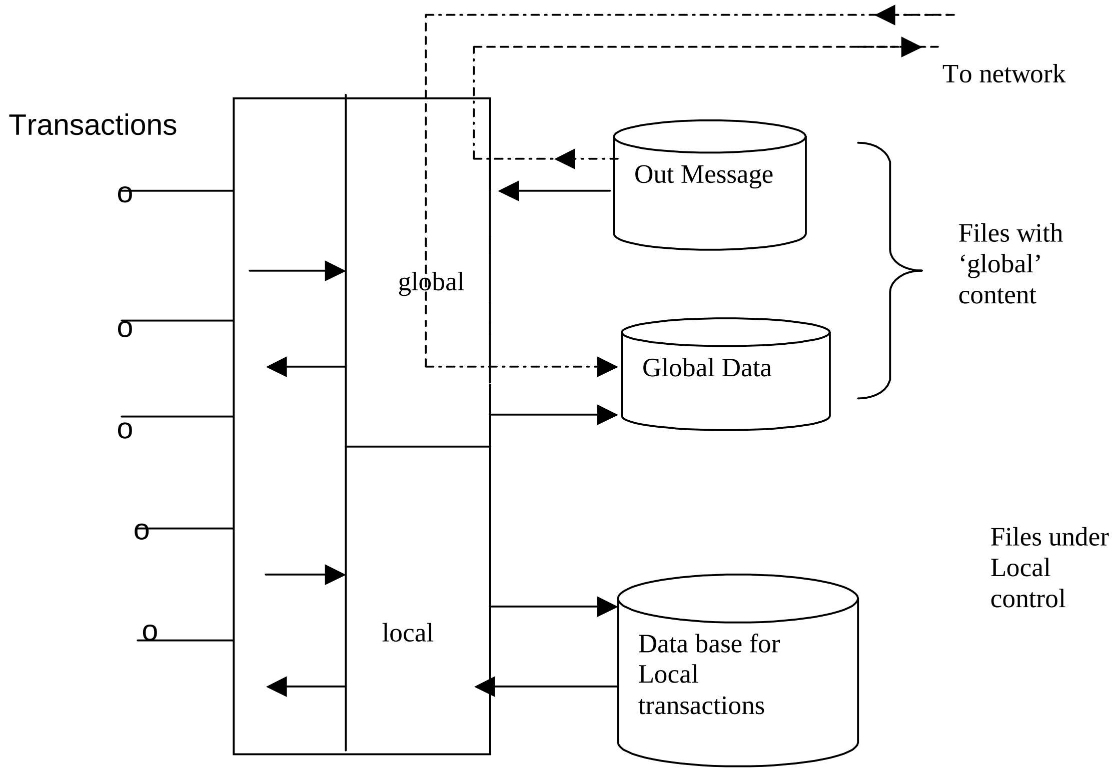

Fig.4: Architecture of a typical node in an Information Network showing The distinction between local and global data bases.

5.2 <u>Detailing the file design</u>

File requirements and design at each node has to take care of the following factors:

a. Split between information of Global and Local significance.

b. Types and No. of transactions being captured

c. Whether processing of local transactions to form messages to update global files can be pre-programmed or requires manual intervention.

d. Mode of access to local data base: Multi-tasking environment, Batch processing, etc.

e. Rate of change in local managerial information needs.

f. Amount of information to be held in the data base.

Files for inter-nodal communication are designed taking into consideration the following factors:

a. No. of queries and updates at each node and their dependence upon information generated at specific other nodes.
b. Cost of communication between nodes.
c. Response time required at each node.

Copies of these files may have to be maintained depending upon criteria (a) and (b). Updates could be made at the source node and sent to all destinations containing copies of that file. An alternative is to hold an up-to-date cumulative copy of all global information in some one node, and relevant portions as non-local files at each node. (See Fig.4).

Response time requirements define the type of communication channel to be used. One can also limit the use of global information to a certain period during the day when lines are available. This would be specially economical where we desire to make 24 hour use of existing trunk telephone capacity. If this option is explored, it could be made semi-automatic by defining 'global' query-and-answer and updating formats which could be prepared and stored during normal working hours for transmission at the appropriate time.

5.3 Language and Software at each node

The Local users should be able to develop new application packages themselves and to add them on to the system. This implies the availability of a higher level user-oriented language on the nodal minicomputers rather than the more commonly used programmer-oriented Assembly language.

Fixed formats for inputs and outputs in a transaction-oriented system make the system very rigid. It becomes difficult to adapt it to changing needs. Instead of fixed formats, the users should have available to them what amounts to a format-describing language so that they can add more and more query—response packages to enhance the power of the system.

It should be noted that systems with fixed formats as in Airlines reservations are basically 'operator-oriented' - intended to be used by large numbers of clerks with only a brief training. User-oriented systems on the other hand require more freedom for the (professional) user and in turn provide a greater flexibility and power to the system.

5.4 Nodal Structure

In a hierarchical network, the internal structure of the nodes would differ widely, not only between levels but possibly even at the same level. If 80% of the information at each lowest-level node is local and 20% is global with reference to the next higher level, and if there are about 10 nodes at this level, this would mean (10 x 20% =) or computational need of at least 200% at the higher level. 2f the lowest level uses one or two microcomputers or cassette-based programmeable calculators, the nodes at the next higher level might be equipped with minicomputers. In turn the top level would have one or more fully equipped minis or 'midi's.

Another advantage of such a structure is that it is expandable and allows for differential growth of the nodes. Today's micro-programmeable minis can have 4 to 250 K or more of 16 bit memory and can directly access from 5 to 120 of disc store, in modular increments.

It should be possible to achieve file transparency between nodes. This can of course be done in sever8l ways. For instance, by standardising on very simple files throughout the system. In order to maintain the user-orientation especially at lower levels, the file structures at those levels might not be very 'efficient".On the other hand, efficiency in computer use is likely to be relevant as a design criterion at higher levels. At the same time, the computer equipment at higher levels is more likely to be able to support more sophisticated indexing systems. These could be used to provide compatibility, if not transparency.

5.5 User maintainability

Computing system hardware and software, at each node must be easily maintainable and should not place stringent demands on the power supply and ambient conditions. This implies facilities like automatic power-fail and restart routines, and a good deal of 'transparency' in the working of the system. Efficiency is much less important than reliability, where that is interpreted as the user knowing that all systems are functioning. Unless these conditions are met, in formations hardware i4ll not be welcomed at lower levels of the orgnnisational and geographical hierarchy and the Information 'network' will not come into being. It is essential to have diagnostics and a good debugging system for local users who will develop their own applications software.

5.6 Indigenous input

One of the prime criteria should be the use of indigenous hardware and software and indigenous system-design skills. There is no point in paying for 'invisible imports' of system architecture in addition to the inevitable imports of certain hardware and of basic software. At the same time, the product policies of indigenous manufacturers - including those supported by public funds - should be oriented to meet the real needs of the priority sectors. Mass-production of a micro-programmeable 16-bit CPU in collaboration with one of the half dozen top brands, with the foreign exchange component financed by specialisation in one or more special purpose devices, cards, or inter-faces for export to the collaborator would seem to fit well into such a need-based computer product policy, in preference to undertaking the production of a whole variety of CPUs, devices and systems alone. The only way our informatics industry consisting of hardware and software companies and systems houses can progress is by being even the chance to apply their skills for priority purposes within the country. At present far too many of our informatics professionals are working on oversees problems for lack of work from the government at home.

6. Relevance

Unlike in the west, the computer resources in India are, and will be limited. Hence, a judicious use of data processing ability must be made for development in priority sectors. This puts a responsibility on all concerned - the users-managers who pay for their, the professionals who build and operate them, the manufacturers who supply them, the educational agencies which disseminate knowledge, the policy makers in government who lay down the guidelines: At present each of these groups has a different perception of the problem and their efforts to 'solve' it are not mutually supportive. The gainers in the present state of confusion on information system and computer hardware priorities are only the strongest foreign hardware interests, and not our economy or its most vital information systems. The professional community is the worst sufferer, being obliged to work on less important problems on inflexible equipment.

Educational agencies must direct their efforts not merely to meeting the needs of the 104 owners of 1401 computers, but also largely to the potential users and builders of priority Information Networks; Managers in the priority Information Networks; Managers in the priority sectors must *assess* how their efficiency can be raised by linking their operations into an Information Network; Policy makers must review their policies to make possible and encourage much more design work to proceed rapidly on large Information Networks for priority sectors.

BIBLIOGRAPHY

Gopalakrishnan P, Narayanan, K.S., Computers in India, An Overview, Popular Prakashan, August, 1975.

Lande, H.F., International Business Machines Corporation, USA, "Developing Information Systems for Corporate Planning" paper presented at the American Statistical Association, 1967.

Lussato Bruno et al, "L informatique a l'envers", Association for the promotion of decentralised systems and handling of information, Paris, 1974.

Miller, J.G., 'Living Systems: The Organisation", Behavioral Science, Vol.17, No.1, January 1972.

Nissen, Hans-Erik, Specialist Report, "A comprehensive look at administrative Data processing and a technique for applying it when developing information systems", Royal Institute of Technology, Stockholm, Dept. of Information Processing, TRITA-IBADB-4029, 1973.

OECD Proceedings of the seminar on Applications of Computer/Telecommunication Systems, Paris, Nov. 1972.